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SHRIMP CANNING WASTE TREATMENT STUDY

A. Frank Mauldin, et al

Domingue, Szabo and Associates, Incorporated

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Wastewater surveys were performed at several Gulf shrimp canneries over a period of three canning seasons. Water used for each process within the plant was metered and the wastewater was tested for biological, chemical and physical characteristics. Pilot screening tests were made over two canning seasons. Tangential, rotary and vibrating screens were evaluated. A 272 cu m/day (50 gpm) dissolved air flotation pilot plant with chemical addition and pH control was tested at the study plant over two canning seasons. A pilot basket centrifuge was evaluated for sludge dewatering. The study demonstrated that: (1) the waste poundage discharged per pound of raw shrimp processed is similar in most Gulf shrimp canning plants; (2) screening removal of heads and shells can be performed efficiently and with few operational problems; and (3) air flotation showed promise as a wastewater treatment method. When performing properly, treatment efficiencies were good, however, the operation was sensitive and treatment efficiencies that can be expected on a plant scale remain to be demonstrated.

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SHRIMP CANNING
WASTE TREATMENT STUDY

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ABSTRACT

This study reports on work which characterized shrimp canning plant wastewaters and operated a pilot dissolved air flotation treatment system during the 1972 and 1973 canning seasons.

The Gulf Coast shrimp canning plants all utilize the same processing equipment from which the wastewater flows occur. The waste handling is complicated by: (a) the relatively small size of the plants; (b) the lack of prior industry experience in treating wastes; (c) the plants operate only during short, intermittent seasons regulated by State conservation agencies and by the economical availability of shrimp; and (d) the BOD of the effluent waste is approximately 5 to 6 times as strong as domestic waste.

A wastewater survey was conducted at several canneries during the 1972 summer season, the 1972 fall season and the 1973 summer season. Water used for each process within the plant was metered and the wastewater was tested for biological, chemical and physical characteristics.

Pilot screening studies were conducted at the study plant during the fall, 1972 and the summer, 1973, seasons. Tangential, rotary and vibrating screens were tested. All the screen types performed approximately the same with each having its advantages and disadvantages. The tangential screen removed heads and shells from peeler wastewater very efficiently; however, blinding did occur with the total composite wastewater.

A 272 m³/day (50 gpm) dissolved air flotation pilot plant with chemical addition and pH control was tested at the study plant during the fall, 1972, and summer, 1973, seasons. Jar tests were performed during the summer, 1972, season and an effective coagulant, polymer and pH combination was established.

A pilot basket centrifuge was tested for concentration of skimmings. The volumes were reduced to 25 percent of the original and the concentration by percent dry solids was increased approximately 2 times.

This study demonstrated that: (1) the waste poundage discharged per pound of raw shrimp processed is similar in most Gulf Shrimp Canning plants, (2) screening removal of heads and shells can be performed efficiently and with few operational problems, and (3) air flotation showed promise as a wastewater treatment method. When performing properly, air flotation treatment efficiencies were good; however, the operation was sensitive and treatment efficiencies that can be expected on a plant scale remain to be demonstrated.

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SECTION I

CONCLUSIONS

1. The wastewater characteristics for shrimp canning and processing wastes have been generally established. Significant variations in wastewater concentrations and flows were found between plants. The total discharged pollutants in kg /100 kg of raw shrimp processed, however, were similar between plants. The variations in hydraulics and wastewater concentrations between plants will make wastewater surveys of each individual plant necessary.
2. The peeling area generates the largest volume of wastewater and the greatest weight of wastewater pollutants in a shrimp processing plant. The doveining operation also contributes significant amounts of wastewater pollutants. Some operations such as retort cooling, can cooling and conveyer spray water have very low concentrations of pollutants but contribute significantly to the total wastewater flow.
3. Water conservation for most of the shrimp processing and canning operations is feasible. The use of dry conveying equipment; the metering and control of water to process units; and the control of washdown water flows will materially affect total water use and total pollutant discharge.
4. Several screen types were evaluated with peeler wastewaters. All the test screens performed well without blinding with the correct screen openings. No ideal screen was found, however, because all of the test screens exhibited advantages and disadvantages.
5. Dissolved air flotation was demonstrated to be an effective treatment operation in treating shrimp canning wastewaters. Screening is a necessary pretreatment operation, however, in order to reduce the total settleable material. An efficient coagulant system and good pH control are required for good degrees of pollutant removal. Removals of 40% to 50% protein, 75% BOD, 70% COD, 90% suspended solids and 90% oil and grease were demonstrated on a pilot scale.
6. The dewatering of screenings and dissolved air flotation sludge will be necessary for economical disposal. Centrifugation of dissolved air flotation sludge was demonstrated to decrease the volume 4:1 and increase the total solids dry weight by 2:1.

SECTION II

RECOMMENDATIONS

1. Those in plant changes which will affect reduction in water use should be instituted. These will consist of substituting dry conveyors, where feasible, for flume conveying; installation of meters and adjustable flow control valves to eliminate excessive water flow to unit processes; and changes in the washdown procedures to use vacuum units and to otherwise control the volumes of water used for washdown purposes.
2. The shrimp canning industry should press the process equipment supplier to develop more water-efficient equipment and to provide guidance in the most efficient operation with the minimum quantity of water. Changes in the process equipment should also be made to reduce the soluble fraction of pollutants discharged in order to increase the treatability of the wastewater.
3. Each water supply should be metered and the flow of water to process units should be metered to enable fine control of flow rates and to allow record-keeping of water use which should be instituted on a continuing basis.
4. The possibility of water reuse should be pursued with the other federal regulatory agencies. A demonstration of a suitable method would be helpful in effecting acceptance of the reuse of water in peeling and other non-contaminating plant uses.
5. There should be a continuing program to collect water use and analytical data in an attempt to detect variations with types of plant operation and the types and age of shrimp being processed.
6. The successful DAF treatment method demonstrated on a pilot plant basis should be operated on a plant scale with good control and collection of complete performance data to establish the feasibility and efficiency of these units on a plant scale.
7. Additional studies should be made to determine best methods for handling separated solids and sludge developed from the DAF process.
8. Studies should be continued to find a marketable value and a practicable way of developing marketable quantities of waste protein from cannery waste treatment facilities.

SECTION III

INTRODUCTION

The American Shrimp Cannery Association sponsored this study for the purpose of seeking to develop an economical, practicable method of effectively and efficiently treating the waste waters from shrimp canning plants. This association consists of twenty-two member firms as listed in Appendix D. The joint efforts through the association were aimed at accomplishing that which many small, individual canners could not individually do.

The shrimp canning plants generally process from 9,000 to 18,000 kilograms (10 to 20 tons) of raw shrimp per day on a single shift basis. The largest plants are capable of processing up to 55,000 kilograms (60 tons) per day with a two-shift operation. These plants receive their raw shrimp from small commercial fishing vessels of two or three-man size and a few larger vessels headquartered between Key West, Florida and Brownsville, Texas. In the central Gulf area alone, there are more than 10,000 registered small commercial fishing boats. These represent the livelihood of more than 30,000 families. The canning plants themselves employ more than 4,000 workers during the peak operating season. Some of these fishermen and plant workers live in remote coastal areas where canneries represent the principal or, in some cases, the only employment available. These shrimp canning plants, many of which are remotely located, are now discharging wastes into rivers, bayous, bays or other adjacent waterways. Some are located in communities where public sewer systems receive the wastewater.

The shrimp fishery in the Gulf of Mexico has been for years one of the most valuable in the United States. Raw shrimp production in Louisiana alone has increased from approximately 4.5 million kilograms (5,000 tons) at the turn of the century to over 453 million kilograms (500,000 tons) annually in some recent years. Catches of white shrimp (*Penaeus setiferous*), brown shrimp (*Penaeus aztecus*), and pink shrimp (*Penaeus duorarum*) are the most common in the Gulf of Mexico. These shrimp spawn during the spring and summer. Eggs are deposited directly into the waters where they drift with tides and currents. The eggs hatch into tiny creatures similar to mites or ticks which grow to about one quarter of an inch size and begin to move into the shallow waters of the bays and bayous. These inside waters serve as nursery grounds for the young shrimp. They grow rapidly as the water begins to

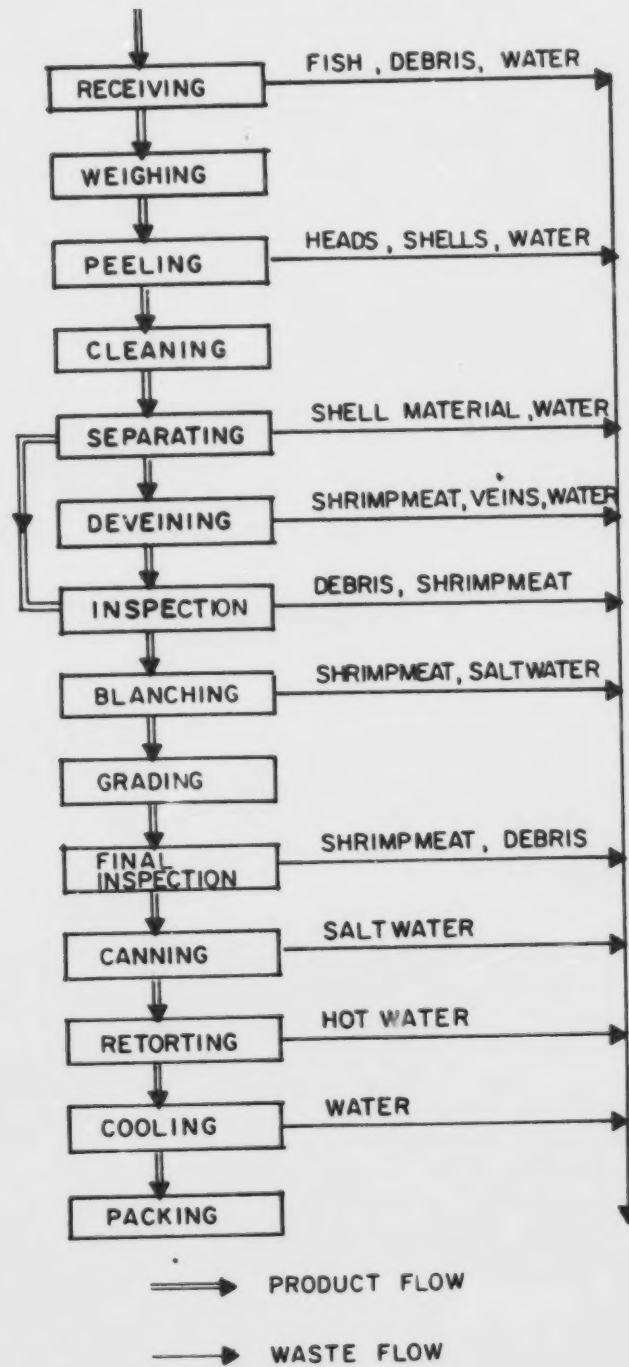
warm and migrate to larger bodies of water, eventually reaching the Gulf of Mexico and/or the Atlantic. Because of this continuing cycle, the size of the individual shrimp in a catch varies constantly, with the larger sizes occurring in the outside waters.

Shrimp are caught primarily in coastal waters using trawls drawn on the floor of the water body. Most of the shrimp are dead when brought to the surface, and the remainder die shortly thereafter. Continued refrigeration (usually with ice) is necessary to preserve this very perishable commodity. Of necessity, the raw shrimp processor must be located close to the fishing grounds and must be able to process the catch rapidly when it is docked. Much of the Gulf Coast catch is handled as a raw product directly to markets and consumers, some is processed and frozen, and up to 50 percent is canned.

The canning of shrimp was first successfully done in 1867 by George W. Dunbar, an enterprising New Englander who settled in New Orleans and operated a cannery after the Civil War. From this difficult and trying beginning, an industry has developed which consists of approximately 70 shrimp canners in the United States, 25 of which are located on the coast of the Gulf of Mexico. The Gulf Coast Canneries are primarily in Louisiana and Mississippi on bays, or bayous or within short trucking distance of the docks. These canning plants have for many years been, and most remain, family enterprises. The canneries compete for the available supplies of raw shrimp and generally obtain and process the smaller sizes. Therefore, the economical operating period is generally during the short spring and fall seasons when shrimp may be taken in the regulated coastal waters. Because of the controlled seasons, the variables of supply and the market price, the competition for the raw shrimp is great and no plant is assured that it will operate on a continuous schedule. Nevertheless, each plant which operates must be able to handle its perishable raw shrimp supply in a short time. Therefore, plants have developed along the same, most efficient mechanical operating basis. Most of the equipment is of the same or similar manufacture, and the wastes created by the operating units have very similar characteristics.

The operations in a shrimp cannery are basically the same the world over, as shown in Figure 1. Raw shrimp are first thoroughly washed and separated from debris or trash and unsuitable materials. The raw shrimp are peeled and deveined with mechanical devices developed especially for the shrimp industry. Figure 2 shows a Laitram Model A peeler. Heads and hulls are removed, pieces of shell and legs are separated and the remaining tail meat is separated from the waste. In the deveiner, shown in Figures 4 and 5, the back of the shrimp is split by a unique razor edge device, the back strip or vein is removed and the cleaned, peeled and deveined meat is again inspected. Following this, there is a pre-cooking or blanching process for 3 to 5 minutes in boiling brine solution, which curls the meat, extracts moisture and

Figure 1 GENERAL PROCESS SCHEMATIC
SHRIMP CANNING



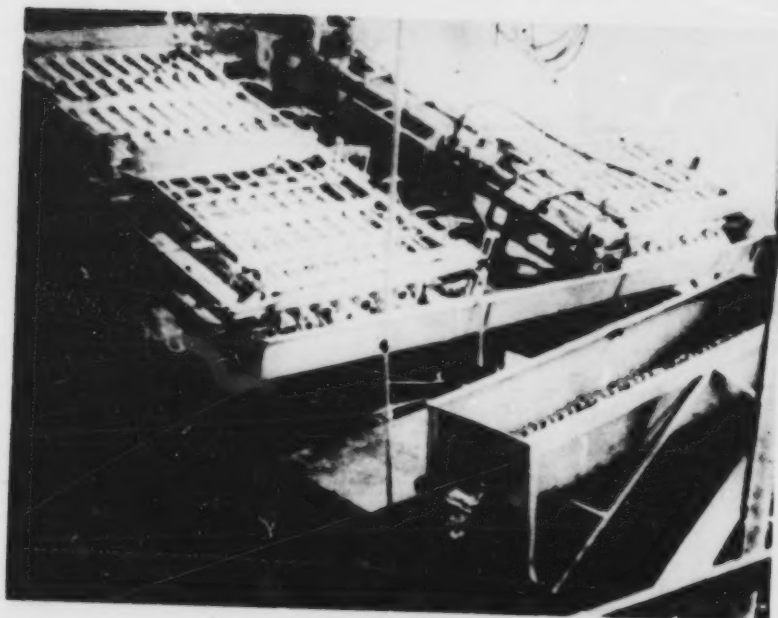


Figure 2. SHRIMP PEELER AND CLEANER

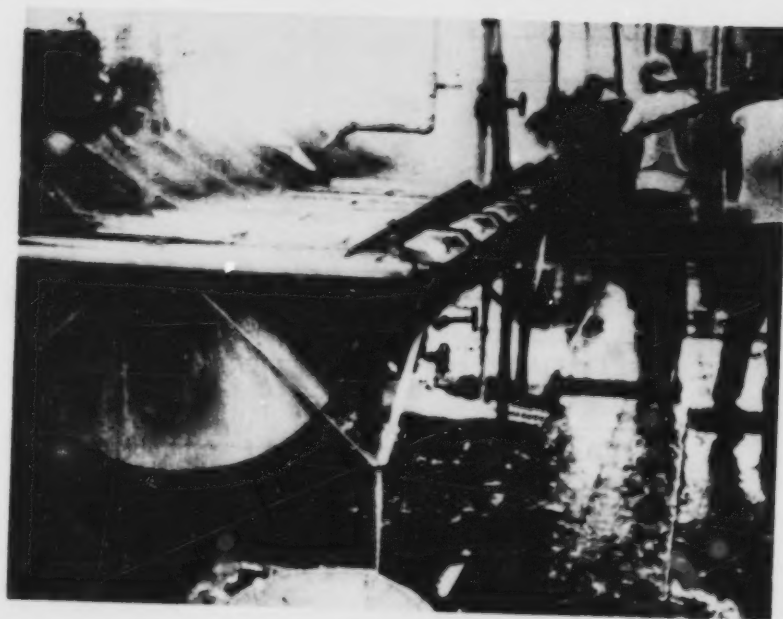


Figure 3. SHRIMP BATCH BLANCHER

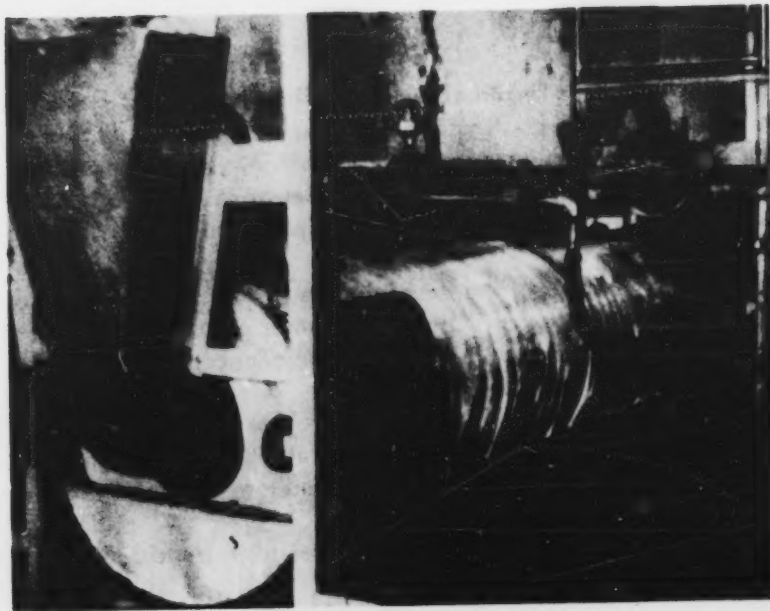


Figure 4. SHRIMP DEVEINER VEIN REMOVAL DRUM

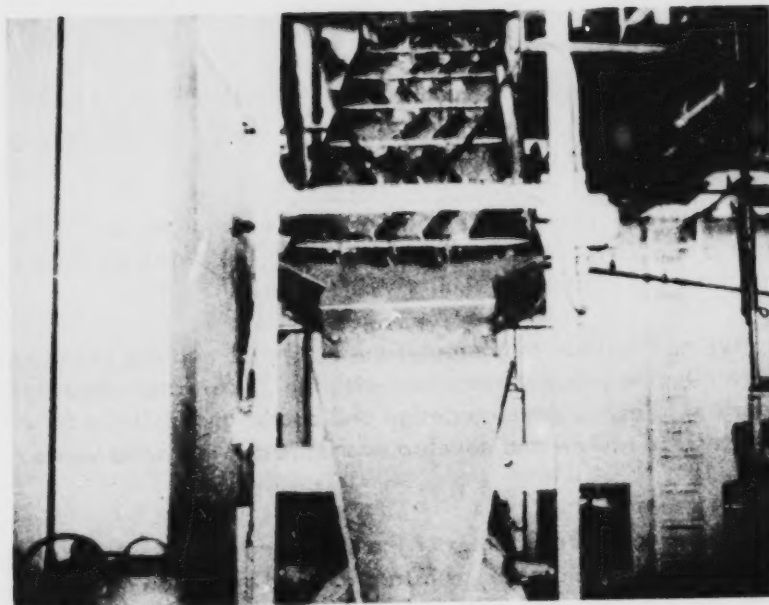


Figure 5. SHRIMP DEVEINER VEIN EXPOSING RAZORS

solubles and develops the pink or red color of the finished product. A batch blancher is shown in Figure 3. After cooling and drying and further inspection and grading, the shrimp are packed, on a scaled weight basis into the appropriate size can, then mechanically sealed and retorted for 12 minutes at 121° C (250° F). After cooling, the cans are labeled and are ready for shipment to market.

The waste from washing, peeling, and deveining constitutes the strongest and largest wastewater volume. This, combined with the other process and plant wash-down water, constitutes the wastewater flow from the cannery.

In seeking a solution for the wastewater disposal problems being faced by these plants which have a very high interest in an unpolluted water environment, there are several factors which are recognized as being unique. Some of these are:

- a. There is a lack of prior industry experience in treating shrimp canning wastes.
- b. The plants operate during short, intermittent periods as a result of state conservation regulations and the availability of the raw shrimp.
- c. The combined plant effluent is five to six times as strong as domestic waste.
- d. There are no known toxic materials in the waste discharge, but these wastes do contain shrimp protein which furnishes nourishment to the marine life in the receiving waters.

The study of necessity included a review of literature seeking the available information on shrimp processing, shrimp waste analyses, shrimp waste treatment and waste treatment processes applied to similar wastewaters.

It was an objective of the study to characterize the shrimp canning plant wastewaters, to review canning process operations with regard to water conservation, to perform pilot scale studies, to develop design and operational criteria for a suitable treatment method and to review and develop economic data on solid waste recovery and disposal.

This report seeks to set forth the findings of the study and to present data for evaluation and application to the design, construction and operation of wastewater treatment systems for the shrimp canning industry, particularly on the Gulf Coast.

SECTION IV

LITERATURE REVIEW

GENERAL

A literature review is presented here of shrimp canning wastewater characteristics and similar wastewaters plus treatability by screening and dissolved air flotation. The reviews of other investigators will only include the part of their work of interest to this study.

WASTE CHARACTERISTICS

The FWPCA (1) in 1968 conducted a survey of seafood processing plants in Westwego, Louisiana to determine their impact on an existing domestic sewage treatment plant. Two of the plants surveyed were shrimp canning plants. The plants surveyed by the FWPCA were also surveyed for this study and are plants A and B which are defined in Section VI of this report. The FWPCA report made the following general comments about the characteristics of shrimp canning wastes:

"The seafood waste waters appear to be about 10 times as strong organically as normal domestic sewage. This additional strength is principally related to dissolved organic material. While the suspended solids concentration in the seafood wastewater is about twice that measured in the domestic sewage, it is within the range of that expected from a strong domestic sewage. There was no indication of materials toxic to treatment organisms in the seafood wastewaters.

The seafood wastewaters tended to spoil rapidly and become odorous even when stored under refrigeration. While this was quite troublesome in the laboratory and interfered with the performance of some tests, it was an indication of a rather rapid breakdown of the organic material in the wastewaters. An aerobic K factor of 0.18/day to the base 10 was obtained using the bottle technique on a composite sample from Plant A. There was no indication of toxicity during the test. There was an indication of nitrification

beginning with the third day of the test."

The wastewater characteristics of the composite discharge from Plants A and B are shown in Table 1. No plant production data was available to compute a pollutants/raw shrimp relationship. Therefore, the wastewater data is difficult to compare directly. Table 1 indicates that the wastewater from Plant A was much more concentrated than from Plant B. Also, the flow rate was higher from Plant A making the weight/time value from Plant A approximately twice that of Plant B.

Table 1. CHARACTERISTICS OF SHRIMP PROCESSING WASTEWATER
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION DATA (1)
WESTWEGO, LOUISIANA 1968

Parameter	Plant A		Plant B	
	mg/l	kg/hr.	mg/l	kg/hr.
TSS	-	27.6	239	17.7
VSS	-	24.0	207	16.3
Set. S.*	4.50	-	2.70	-
BOD	1878	217.7	1188	92.1
COD	3874	444.0	1536	119.7
OSG	42	5.0	106	8.2
Tot. -N	278	32.2	160	12.2
NH ₃ -N	45	5.4	22	1.8
Org. -N	233	27.2	138	10.9
NO ₃ -N	4.6	0.5	3.1	0.2
Flow	2,790 m ³ /day		1,875 m ³ /day	
*ml/l				

The USDI (2) describes the chemical composition of shrimp wastes in terms of protein, chitin and calcium carbonate. This also compares the composition of wastes from hand picking and mechanical picking operations. In this publication the percentage of protein and chitin (a complex polysaccharide, not readily biodegradable) are lower in mechanical picking wastes but the percentage composition of calcium carbonate is approximately twice that of hand picked waste. These percentages cannot be logically explained. The results of that study are:

Table 2. COMPOSITION OF SHRIMP WASTES (2)

Source	Composition (%)		
	Protein	Chitin	Calcium Carbonate
Hand Picking	27.2	57.5	15.3
Mechanical Picking	22.0	42.3	35.7

However a study by CRESA (3) reported a different composition for mechanically picked Alaskan shrimp wastes. They reported a composition of 37% protein, 28% chitin, and 35% calcium carbonate and other, which indicates a much larger percentage of protein in the wastes.

CRESA also reported the amino acid composition of spray dried shrimp waste protein. The results are shown in Table 3 where the shrimp protein composition is compared to the protein composition of casein. In this study feeding tests were conducted on rats with shrimp waste proteins. The protein showed a marked deficiency in sulfur containing amino acids which could be corrected by supplementation with either cystine or methionine. Otherwise the shrimp waste proteins were found to be equal to casein in nutritional value and there were no toxic effects noticed.

CRESA also reported an average COD value of 1.37 mgO₂/mg organic matter for shrimp wastes and an average COD value of 1.24 mgO₂/mg organic matter for the shrimp chitin alone. Also, an average BOD-5 value of 0.653 mgO₂/mg of organic matter for shrimp wastes. This would make the BOD-5/COD ratio equal to 0.48.

Table 3. AMINO ACID COMPOSITION OF SPRAY DRIED SHRIMP WASTE PROTEIN (3).

Amino Acid	Shrimp Protein %	Casein Protein %
Lysine *	8.34	6.02
Histidine *	2.97	2.31
Arginine *	8.06	2.41
Aspartic Acid	8.63	4.45
Threonine *	3.91	3.81
Serine	4.69	5.88
Glutamic Acid	17.8	21.90
Proline	4.54	15.71
Glycine	7.52	1.16
Alanine	7.14	1.47
Cystine ^a		
Valine *	5.62	7.91
Methionine *	2.60	2.75
Isoleucine *	5.17	3.91
Leucine *	8.14	11.07
Tyrosine	3.61	2.72
Phenylalanine *	5.05	5.46
Tryptophan *	0.73	1.00
Total	104.52	99.94

* essential

^a not determined

CRESA compared the shrimp waste distribution when using raw peelers (Laitram Model A) and peelers using steam treated shrimp. The results indicate that a considerably higher fraction of waste organics are lost to the wastewater when using the raw peelers. All of the Gulf Coast canners use the raw peelers at present. The results are shown in Tables 4 and 5.

Table 4. WASTE DISTRIBUTION IN SHRIMP PROCESSING (3)
A. Raw Peeling

Analysis

Sample	Weight grams	Total Solids %	Suspended Solids %	C. O. D. mg/l	5 Day B. O. D. mg/l	N mg/l
Raw Shrimp	1,815	25.7		304,000		
Washed shells	1,292	18.3		173,000		
Cooked meat	439	19.8		267,000		
Cooking and cooling water	1,046	4.26	0.43	36,300	18,000	5,850
Peeling and washing water	6,248	1.81	0.49	23,900	9,800	2,180

Distribution

Sample	Solids			C. O. D.	
	grams	Total %	Waste %	grams	Waste %
Raw shrimp	467	100		552	
Washed shell	236	50.5	60.0	224	57
Cooked meat	87	18.6		117	
Cooking and cooling water	44.5	9.5	11.3	38	10
Peeling and washing water	113	24.2	28.7	130	33

Table 5 . WASTE DISTRIBUTION IN SHRIMP PROCESSING (3)
B. Peeling after Steaming

Analysis

Sample	Weight grams	Total Solids %	Suspended Solids %	C. O. D. mg/l	5 Day B. O. D. mg/l	N mg/l
Raw Shrimp	1,818	25.7		304,000		
Washed shells	1,325	20.1		173,000		
Cooked meat	470	21.4		267,000		
Cooking and cooling water	2,563	1.58	0.37	19,200	9,600	2,500
Peeling and washing water	5,865	1.24	0.63	17,500	7,800	1,680

Distribution

Sample	Solids			C. O. D.	
	Grams	Total %	Waste %	Grams	Waste %
Raw Shrimp	467	100		505	
Washed shells	267	57.2	70.2	254	70
Cooked meat	101	21.6		136	
Cooking and cooling water	40.5	8.7	10.7	34	10
Peeling and washing water	72.8	15.6	19.1	84	23

Soderquist (4) reported the wastewater discharged from the unit operations in Gulf Coast Shrimp Canneries. Those results are shown below in Table 6:

Table 6. WASTEWATER MATERIAL BALANCE (4)
GULF COAST SHRIMP CANNERIES

Unit Operation	% of Average Flow	Range, %
Peelers (Model A)	58.1	42.1 - 73.0
Washers ^a	8.8	8.0 - 9.9
Separators	6.9	5.1 - 9.2
Blancher	1.6	.006 - 2.5
De-icing	4.2	.005 - 7.4
Cooling & Retort	12.1	3.0 - 19.5
Washdown	8.3	6.9 - 9.6

^aCleaners

As can be seen above, a large percentage of the wastewater from a shrimp canning plant originates at the peelers. A considerable volume of water is used for can cooling and retorting but this water is relatively unpolluted chemically and biologically.

Soderquist also reported the average wastewater characteristics of four Gulf shrimp plants. This data is shown in Table 7. Data was reported in terms of concentration and weight of pollutants/weight of raw shrimp processed. This latter method is the only reasonable method of comparing the discharges from different canneries. In comparing the coefficient of variation for COD the concentration value is 28% of the mean and the kg/kg value is only 18% of the mean.

Soderquist also reported a product material balance. He reported that the food product was approximately 20% of the raw product, the by-products such as dried

Table 7. GULF SHRIMP CANNING WASTEWATER (4)
AVERAGE CHARACTERISTICS OF FOUR PLANTS

Parameter	Mean	Standard Deviation	Coefficient of Variation % of Mean	Range
Flow Rate, cu m/day (mgd)	788 (0.208)	92.7 (0.0215)	12	695 - 905
Flow Ratio, l/kg (gal/ton)	46,900 (11,000)	9800 (2350)	12	(0.184 - 0.239)
Settleable Solids, ml/l	13.9	5.3	21	33,000 - 57,000
Settleable Solids Ratio, l/kg	520	470	21	(7900 - 14,000)
Screened Solids, mg/l	--	--	38	5.4 - 31
Screened Solids Ratio, kg/kg	--	--	90	184 - 978
Suspended Solids, mg/l	802	459	--	--
Suspended Solids Ratio, kg/kg	37.7	15.2	--	--
5 Day BOD, mg/l	1,081	216	57	483 - 1,100
5 Day BOD Ratio, kg/kg	46	--	40	15.9 - 50.1
COD, mg/l	2,296	653	20	1,008 - 1,432
COD Ratio, kg/kg	109	20	--	43 - 61
Grease and Oil, mg/l	258	169	28	1,975 - 2,658
Grease and Oil Ratio, kg/kg	11.0	9.8	18	86 - 122
Organic Nitrogen-N, mg/l	196	62	66	148 - 759
Organic Nitrogen-N Ratio, kg/kg	7.6	7.7	88	5.4 - 36.4
Ammonia-N, mg/l	12	5.4	32	39 - 290
Ammonia-N Ratio, kg/kg	0.51	0.12	102	1.9 - 13.4
pH	6.7	--	46	7 - 14
			24	0.22 - 0.47
			--	6.5 - 7.0

shells were 65% of the raw product and waste was 15% of the raw product.

TREATABILITY BY SCREENING

The pre-treatment of shrimp canning wastewaters by screening has been demonstrated by Peterson (5) with a 5.49 meter (72 inches) wide 1.0 mm (0.040 inch) opening tangential screen. The duration of the run was 1.5 hours and the flow was approximately 0.568 m³/sec. (900 gpm). The data follows in Table 8 below:

Table 8. SCREENING OF ALASKAN SHRIMP CANNING WASTEWATER (5)

Parameter	Before Screening mg/l	After Screening ^a mg/l	% Removal
COD	2734	2360	13.7
Total Solids	2680	1900	29.1
Total S.S.	1160	720	37.9
Settleable Solids ^b	50	6	88.0
Turbidity ^c	215	193	10.0

^a Bauer "Hydrasieve" - 1.0 mm Opening Tangential Screen

^b ml/l

^c JTU

Peterson suggested that flow over the screen was extremely important because sufficient flow was required to wash the solids across the screen but the flow could not be excessive so that solids were carried off the end of the screen. He felt that the screens tested were only efficient in removing settleable solids. It was obvious from his findings that most of the solids were in the dissolved and finely suspended states.

Other studies have investigated screening of salmon and tuna wastes. Although there are probably many differences in the screenability of shrimp wastes and other fish wastes enough similarities exist to justify a review.

Peterson (5) also investigated screening of salmon wastes with the same type screen

as used in his shrimp waste screening study. The salmon study used a 0.46 m (18 inch) wide pilot model tangential screen (Bauer "Hydrasieve") where the shrimp study used a 5.49 m (72 inch) wide plant scale tangential screen. For the salmon study the flow rate was 246 m³/day (45 gpm), the duration of the run was 2 hours and the screen opening was 1.0 mm (0.040 inch). The results of the salmon test are as shown in Table 9 below:

Table 9. SCREENING OF SALMON PROCESSING WASTEWATER (5).

Parameter	Before Screening (mg/l)	After Screening ^a (mg/l)	% Removal
COD	42,256	19,075	54.9
Total Solids	24,915	11,425	54.1
Total S. S.	17,400	7,580	56.4
Settleable Solids ^b	290	145	50.0

^a1.0 mm Opening Tangential Screen.
^bml/l

Peterson comments that blinding of the screen was a problem and a periodic spraying consisting of a few seconds every minute near the top of the screen relieved the problem. He further comments that salmon wastes are extremely variable and heterogeneous in nature and the results above are only indications of what could be expected over a long time period. It does seem obvious from the results of this study, however, that salmon wastes are much more concentrated than shrimp wastes and the percentage reduction over the screen are much greater for all test parameters.

Dehn and Holz (6) also performed a study on salmon processing wastewater where they investigated three types of screens: a tangential screen (Dorr-Oliver "DSM"), a vibrating screen (Sweco "Vibro-Energy Separator") and a spinning cylindrical screen (Sweco "Wastewater Concentrator"). A summary of their results are shown in Table 10 below.

Table 10. SCREENING OF SALMON PROCESSING WASTEWATER (6).
TANGENTIAL, VIBRATING AND CYLINDRICAL SCREENS

Parameter (mg/l)	% Removal		
	Tangential Screen 0.149 mm	Vibrating Screen 0.42 mm	Cylindrical Screen 0.05 mm
COD	13	30	36
Total Solids	8	17	58
Total S.S.	15	31	34
Settleable Solids ^a ^a ml/l	35	14	100

Dehn and Holz commented that none of the above screens had all the ideal characteristics of producing good effluent quality, high solids concentration, high screening capacity and trouble free operation. The tangential screen was somewhat trouble free and the vibrating screen concentrated solids the best while the cylindrical screen obtained the best effluent quality. The conclusions of these investigators were somewhat noncommittal because of lack of knowledge in ultimate disposal of screenings.

Claggett (7) also investigated screening of salmon wastewaters by different types of screens. A summary of his results is shown in Table 11 below:

Table 11. SCREENING OF SALMON CANNING WASTEWATERS (7).
TANGENTIAL AND ROTARY SCREENS

Sample Location	Total Solids (g/l)
Tangential Screen (Dorr-Oliver "DSM" - 40 mesh)	
Feed	4.5
Undersize	2.5
Oversize	164.0
Removal	44.4%
Rotary Screen (North Sewage Screen - 34 mesh)	
Feed	4.2
Undersize	2.4
Oversize	105.1
Removal	42.9%

Claggett commented that both screens performed well on salmon canning wastewater but a gradual loss in capacity occurred with time with both screens. However, he said this was readily corrected by the use of water sprays.

From the above investigations it appears that no special type of screen was given an overwhelming recommendation. It appears, however, that one could expect a large reduction in settleable solids, good reductions of total and suspended solids, and a small reduction in COD when screening shrimp canning wastewaters. Reductions expected in COD while screening shrimp wastes would be small because the major screenable portions of the waste such as chitin has generally a small COD per gram.

TREATABILITY BY DISSOLVED AIR FLOTATION

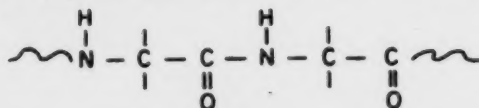
The work performed by Claggett and Wong (7) on salmon wastewaters indicated that DAF could effectively treat fish product wastewaters. Also, the meat packing industry (7) has many plant scale DAF treatment units in operation and they are experiencing good performance. It was recognized, however, that many differences existed between salmon, meatpacking and shrimp canning wastewaters. Therefore, development of an effective coagulant system would be needed for shrimp canning wastewaters.

There are basically four size groups of particles in wastewaters (8). They are: course, which are the larger suspended solids; fine, which are the smaller suspended solids; colloidal; and molecular, which are the particles in solution or dissolved. Of this range of sizes, coagulation can only aggregate the colloidal and larger particles. The suspended solids are relatively easy to coagulate, usually, but efficient coagulation of colloids is quite difficult.

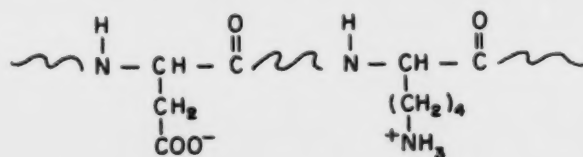
Colloidal particles are electrically charged. Depending upon the wastewater the charge is either positive or negative. The colloids are also very small and the ratio of surface area to their mass is large, therefore, their behavior is influenced greatly by surface phenomena. The combination of large surface area to mass and its electrokinetic property makes the colloid very adsorptive and, therefore, capable of being aggregated or coagulated by adsorbing to another colloid of opposite sign. This continues until the particle is heavy enough to settle.

Shrimp canning wastewater has a very large concentration of protein. Protein is an organic compound and is considered a wastewater pollutant because of the oxygen demand created in hydrolysis and deamination degradation of protein to free fatty acids. The protein molecule contains approximately 54% carbon, 7% hydrogen, 23% oxygen and 16% nitrogen with occasional trace amounts of sulfur and phosphorus (8). The protein molecules are very large and are colloidal in size (9).

Proteins are made up of peptide chains with a structure as follows:



A peptide is made up of amino acid residues with an amide linkage. To every third atom of the peptide chain is attached a side chain. Its structure depends upon the particular amino acid residue involved such as CH_3 for alanine. Some of the side chains contain basic groups such as $-\text{NH}_2$ in lysine and some of the side chains contain acidic groups such as $-\text{COOH}$ in glutamic acid. Therefore, because of the acidic and basic side chains, there are positively and negatively charged groups along the peptide chain (9). The structure is as follows:

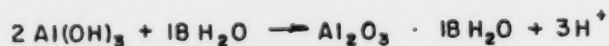


The electrostatic behavior of protein is determined by the relative numbers of its positive and negative charges which is affected by the acidity of the solution. At the isoelectric point the positive and negative are balanced, the migration forces are zero and the solubility is at a minimum. In a solution on the acid side of the isoelectric point, positive charges exceed negative charges and, if on the basic side, negative charges will exceed positive charges.

The trivalent aluminum and iron salts are good primary coagulants with protein wastewaters (7). The stoichiometric reaction of hydrated aluminum sulfate (alum) with water alkalinity is:



Under acidic conditions:



The solubility of the aluminum hydroxide floc is as follows:

$$[\text{Al}^{3+}] [\text{OH}^-]^3 = K_s = 10^{-33}$$

Therefore, the solubility of aluminum decreases with increasing hydroxide concentration or increasing pH. The solubility of aluminum at pH 4.0 is 51.3 mg/l and at pH 9.0 is 10.8 mg/l (14). The aluminum hydroxide floc is least soluble at pH 7.0 and becomes only highly soluble at pH values less than 5.0. Therefore, it

follows that the effect of trivalent aluminum ions on coagulation is not brought about by the ions themselves, but by their hydrolysis products. For a given aluminum ion concentration, the rate and efficiency depends on the pH of the medium (14).

Polyelectrolytes are very effective coagulant aides that form bridges between colloids and charged floc. The polyelectrolytes are actually high molecular weight polymers which contain sites where adsorption can readily take place. Polymers are not affected by pH as significantly as the metal salts. There are basically three kinds of polymers (10): a cationic which adsorbs on a negative colloid or floc particle and which can be used as a coagulant; an anionic, which replaces the anionic groups on colloidal particles and permits hydrogen bonding between the colloid and the polymer; and a nonionic, which adsorbs and flocculates by hydrogen bonding between the solid surfaces and the polar groups in the polymer.

The principle of dissolved air flotation is based on Henry's Law which states that the partial pressure of a gas in equilibrium with a solution is proportional to its concentration in the solution. Therefore, if a pressure greater than atmosphere is applied to a liquid the dissolved air will be proportional to the pressure applied. When the pressure is released, the dissolved air will come out of solution in the form of extremely tiny bubbles. The bubble will preferentially form on a finite nucleus or particle. The chemical coagulation system has created an enlarged particle or floc in the water so the bubble either forms or attaches itself to this floc. The bubble gives the floc added buoyancy and it floats to the surface.

The purpose of a DAF treatment system is to separate and concentrate suspended and colloidal particles in the feed wastewater. Larger particles of the settleable solids size should be removed prior to DAF treatment by screens and cyclones if high density particles are present. Separation of small suspended and colloidal solids depends more on their structure and surface properties than on their size and density. Therefore, DAF treatment plants cannot be designed theoretically or rationally by mathematical equations but by the use of laboratory (bench scale) and pilot scale studies. Factors of greatest importance in designing DAF plants are as follows:

1. Chemical coagulants.
2. Feed solids concentration.
3. Quantity of pressurized air used.
4. Overflow rate.
5. Retention Time.
6. Recycle/Pressurization Mode.

Feed solids concentration and air quantities are usually grouped in a dimensionless air/solids ratio. For a given plant, overflow rate and retention time are proportional to the depth of the flotation tank. The results for this study will include both values.

The air/solids ratio can usually be related to effluent suspended solids. Solids in this dimensionless ratio is the weight of solids per unit of time in the influent. Air is the weight of air per unit of time released to atmospheric pressure in the flotation cell. The weight of air that can be released is proportional to the saturation of air in water, and saturation of air in water is directly proportional to the absolute pressure and inversely proportional to the temperature. Saturation is also dependent on a good mix of air and water. Therefore, the saturation is dependent on the machinery used for this purpose. Eckenfelder (11) proposes the following equation for air saturation:

$$S = S_a \left[\frac{(fP/1.035) - 1}{1} \right]$$

Where: S = air released at atmospheric pressure (cm^3/liter)

S_a = air saturation at atmospheric pressure and given temperature (cm^3/liter)

f = fraction of saturation obtained in saturation tank

P = absolute pressure (KgF/cm^2)

Therefore the air/solids (A/S) ratio would be:

$$A/S = CSQ/S_s$$

Where: C = air density (g/cm^3)

Q = feed flow ($\text{liter}/\text{sec.}$)

S_s = suspended solids ($\text{g}/\text{sec.}$)

The performance of the DAF system depends upon having sufficient air present to float all of the suspended floc. An insufficient quantity of air will result in only partial flotation of the solids and excessive air will give no improvements of suspended solids removal so, therefore, an optimum air/solids ratio for each application exists.

Overflow rate is a function of influent and recycle flow, and the surface area of the flotation cell. Overflow rate is usually expressed in $\text{m}^3/\text{sec}/\text{m}^2$. This term can also be reduced to an equivalent $\text{m}/\text{sec.}$ relationship, so, therefore, it also expresses rise rate in an upflow tank.

The recycle/pressurization arrangement can be of three basic types:

1. Total Pressurization.
2. Partial Pressurization.
3. Recycle Pressurization.

Selection of one of these arrangements should ideally be based on the application of the DAF unit. It is usually, however, governed by the proprietary position of the manufacturer of the system. All three variations operate under the same physical laws and relationships as described earlier and differ only in piping arrangements. The three types are shown schematically in Figure 6.

Total pressurization is straight through with a single pass. The recycle shown in Figure 6 is only for protection of the pump suction during periods of low flow and is not related to recycle pressurization. The advantages of this system includes low capital investment and the ability to inject a high air/solids ratio. The disadvantages are: possible short circuiting; the possibility of shearing delicate chemical flocs; and the possibility of emulsifying oils.

With the partial pressurization system only part of the influent stream is pressurized and the remainder enters the flotation cell under gravity conditions. Again the recycle is only for pump protection during low flow conditions. The advantages are: relatively low capital costs; and the ability to operate under extremely variable flow conditions. The disadvantages are generally the same as full flow pressurization plus a poor ability to inject a high air/solids ratio.

The recycle pressurization system offers an alternative to the previously discussed systems because it represents a significant deviation. With this system the influent flows to the flotation cell by gravity. A portion of the effluent is recycled, pressurized, and released as influent to the flotation cell. The advantage of this system is the ability to incorporate a flocculation tank separate from the flotation cell. This allows an increased detention time for slow developing delicate flocs to form. The floc is then discharged by gravity to the flotation cell and not sheared by a pressurization pump as in total pressurization. Therefore, if delicate floc is a characteristic of the coagulated wastewater, recycle pressurization offers a tremendous advantage. The major disadvantage to this system is high capital and operating costs.

Peterson (5) treated Alaskan shrimp canning wastewaters with a 50 gpm pilot dissolved air flotation (DAF) treatment unit. The unit was a Model 50 Pacific DAF system. Peterson operated the plant with the average conditions shown in Table 12 below:

**Figure 6 AIR FLOTATION ARRANGEMENTS
RECYCLE / PRESSURIZATION**

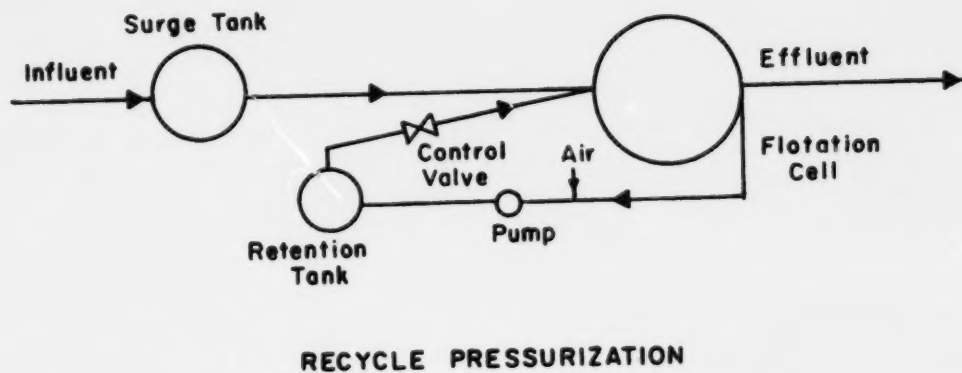
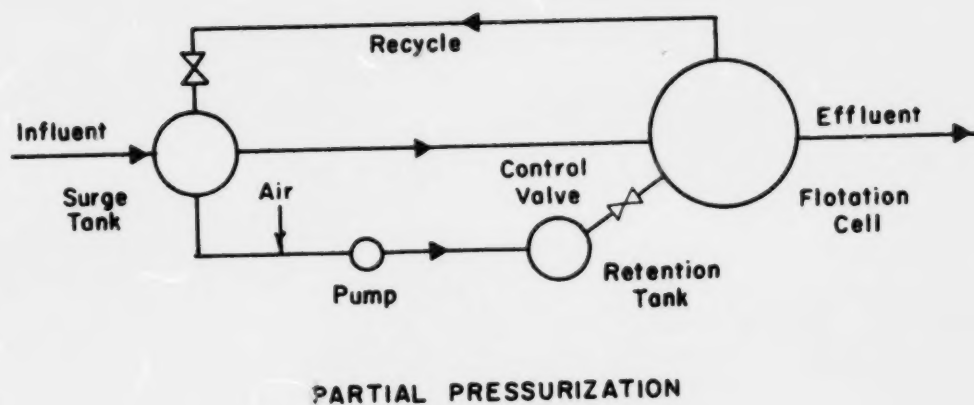
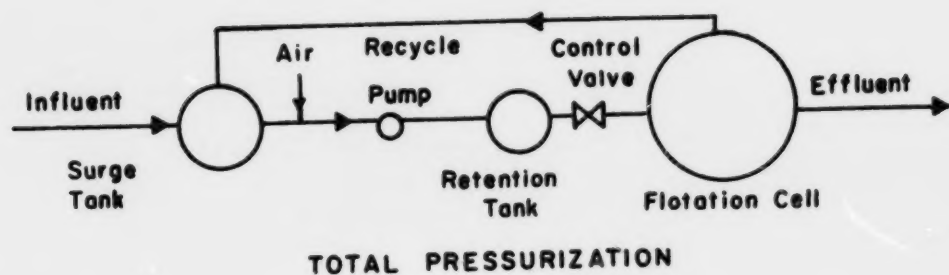


Table 12. DAF TREATMENT OF SHRIMP CANNING WASTEWATERS (5)
OPERATING CONDITIONS

Pre-treatment	Screening with 1.0 mm Opening Tangential Screen
Flow	107 to 328 m ³ /day (20 to 60 gpm)
Pressurization	3.16 kgf/m ³ (45 psig)
Recycle	1:1 at 272 m ³ /day influent
Run Times	1.0 to 4.0 hours
pH	3.0 to 7.0
Coagulant	- Alum
Polymer	- High molecular weight anionic
Alkalinity	- Excess with Na OH

Peterson obtained the average results shown in Table 13 below:

Table 13. DAF TREATMENT OF SHRIMP CANNING WASTEWATERS (5).
AVERAGE RESULTS

Parameter	After Screening	After DAF	% Reduction
COD (mg/l)	4227	1123	73.4
Total S. S. (mg/l)	1090	252	76.9
Settleable Solids (ml/l)	22.3	2.5	88.8
Protein %	0.201	0.114	43.3
Turbidity (ITU)	500	100	80.0

The conditions occurring within the shrimp plant while the pilot DAF work was in progress are unknown for the above study. There were, however, six peelers with four being the pre-cook type (Laitram Model PCA) and two being the raw type (Laitram Model A). The plant was processing small pink shrimp and using a high salinity process water.

Peterson comments on the relative insensitivity of pH. He observed little difference in treatment efficiencies from pH 5.0 to pH 6.0. He also observed a low sludge solids concentration and settleable solids carryover in the DAF effluent. He attributed this problem to the high salinity of the process water and secondary reactions

with the salt and alum.

Claggett and Wong (12) studied the treatment of salmon canning wastewater by DAF. Two seasons of operation using two different pilot systems were reported. In Part I of their study a Pacific DAF system which utilize total flow pressurization was studied. Coagulants were injected with a metering pump just prior to entering the flotation cell. When pH was adjusted, sulfuric acid was metered in at the same point and was controlled manually using a portable pH meter. The operating conditions for all runs were: flow rate, $0.0032 \text{ m}^3/\text{sec}$ (50 gpm) operating pressure, $289.7 \text{ k N/m}^2 \text{ g}$ (42 psig); air injection, 2% by volume. The results are shown below in Table 14.

Table 14. TREATMENT OF SALMON CANNING WASTEWATER BY DAF (8).
PACIFIC DAF SYSTEM

Coagulant		pH	DAF Influent Total Solids (mg/l)	DAF Effluent Total Solids (mg/l)	% Removal
Alum	47 mg/l	6.1	5,400	1,560	71.1
Alum	47 mg/l	6.0	2,290	1,200	47.6
Alum	47 mg/l	6.0	2,800	2,400	15.3
Alum	47 mg/l	6.0	2,600	2,200	15.4
Alum	80 mg/l	5.1	4,180	5,000	-19.6
Alum	60 mg/l				
X-37-1 ^a	5 mg/l	5.8	3,390	3,000	11.5
FeCl ₃	133 mg/l	4.1	1,800	1,180	34.4
FeCl ₃	60 mg/l	5.5	2,860	950	66.8
FeCl ₃	50 mg/l	5.5	6,390	1,200	81.2
FeCl ₃	60 mg/l	5.5	5,580	2,400	57.0
F-flok ^b	1000 ppm	4.0	5,900	1,200	79.7
F-flok	1000 mg/l	4.0	4,200	1,500	61.9
F-flok	1000 mg/l	4.0	1,300	1,400	-7.7
F-flok	500 mg/l	4.0	3,500	1,800	43.6

^a anionic polyelectrolyte

^b a lignosulphonic acid derivative

As can be seen from the above the results are scattered but promising, especially with ferric chloride and F-flok as coagulants.

The investigators commented that ferric chloride when used as the coagulant reduced considerably the value of any by-products produced from captured solids. Ferric

chloride was also observed to be quite corrosive and would require special materials. F-flok had the disadvantage of requiring very low operating pH's. This would also necessitate special construction materials.

The investigators observed that although the DAF system improved clarity of the wastewater considerably, the runs were plagued with considerable carryover of floc and a resultant high settleable solids concentration in the effluent. No final conclusions were drawn by the investigators from their results. They felt more testing under different conditions was required.

In Part II of their study Claggett and Wong used the Favair DAF system which had a rectangular cell and compressed air injection. The unit also had the versatility of allowing effluent recycling and partial pressurization of the influent stream.

Basically four coagulant combinations were tested: alum and sodium hydroxide; alum, sodium hydroxide and zetal A (activated animal glue); alum and lime; and F-flok. Results are shown in Table 15 below.

Table 15. TREATMENT OF SALMON CANNING WASTEWATERS BY DAF (7).
FAVAIR DAF SYSTEM

Stream	Suspended Solids mg/l	Protein mg/l	BOD mg/l	Total Solids (mg/l)
Coagulants: Alum (375 mg/l) and Na OH (75 mg/l)				
Influent	640	1,440	1,775	2,685
Effluent	180	485	475	1,505
% Removal	70	65	73	44
Coagulants: Alum, NaOH and Zetal A (1.0 mg/l)				
Influent	697	1,020	1,275	2,441
Effluent	200	505	381	1,625
% Removal	66	50	70	34
Coagulants: Alum and Lime				
Influent	1,993	1,982	2,833	4,268
Effluent	397	830	633	2,162
% Removal	73	57	79	46

The investigators computed the standard deviation for the runs with a coagulant

system series. The variations were from approximately 20% to 75% of the mean values. The three coagulant systems shown above all gave very similar results. The investigators commented that any of the above three systems could be used in prototype operation.

When using F-flok as the coagulant, the investigators found pH adjustment below the protein isoelectric point (pH 3.8 to 4.2) was required. Dosages were heavy and had to be proportional to total solids in the influent feed or solids carryover resulted. A distinct plus for F-flok, however, was the large percentage of protein captured (approximately 70%).

BY-PRODUCT RECOVERY

CRESA (3) investigated the recovery of high grade protein from shrimp shells and meat by caustic extraction. Their laboratory studies showed 85% to 90% recovery of protein by this technique as compared to approximately 55% recovery of protein by isoelectric precipitation alone. They proposed a protein recovery system consisting of a caustic extractor, then isoelectric precipitation of protein, then a screw press for concentration of remaining solids. They reported that expected yearly operating and depreciated capital costs for this system for the Kodiak Alaska area would be approximately 1.25 million dollars. Expected average income would be approximately 1.5 million dollars/year or 0.25 million dollars/year profit before taxes. The economic analysis assumed shrimp protein would sell at \$0.33 per kg. At the present a much larger price could be obtained. This system appears economically feasible for the Kodiak Alaska area.

An alternative to processing wastes to high grade protein is to make a crude waste meal. This can be done by individual canners or by a rendering plant (13). However, there are many problems in using this approach, including economic and technical. Crude waste from shellfish cannot provide the major source of protein in livestock feeds because it would contribute an excessive proportion of calcium (14). Digestibility in animals depends on non-protein components of the diet, including calcium (14). Novak (14) reports a new method for decalcifying meal by using a screening technique. Therefore, for some application refining of the crude meal to a usable meal may be feasible.

Shrimp wastes in the past have been sold as mink food (13), as a food supplement supplying red pigment for flamingos and trout (15) and as a flavoring for human food in fish flours (16). These methods of utilization are, however, declining because of development of synthetic substitutes (17).

Mendenhall (13) reports that fertilizer and livestock feed is apparently the only

established market for crude shrimp waste meals. Also, Mendenhall reports this market is not large and crude meal for this purpose seems to offer little, if any, profit. Also, the protein available from crude shrimp waste meal is very small in quantity compared to fin fish protein. Therefore, the availability of fin fish protein will control the market price and would make the economic feasibility of crude shrimp meal very uncertain.

A refined derivative of chitin, chitosan, has many commercial uses (13). However, the commercial feasibility of refining chitosan from shrimp shells would be poor, because of, (a) the small supply available at any location and, also, (b) the seasonal nature of the shrimp processing industry.

It appears that, although isolated uses and markets for crude shrimp waste meal can be found, the overall economics appear discouraging for a new installation. However, the economic feasibility of refined protein appear good in certain areas, such as Kodiak, Alaska.

SECTION V

STUDY OBJECTIVE AND APPROACH

The objective of this study was to demonstrate on a pilot scale a wastewater treatment plant for the Gulf Coast shrimp processing industry.

This general objective was considered necessary to help solve the wastewater problem of the Gulf Coast shrimp processors. No canning plant on the Gulf Coast had any experience in the treatment of wastewaters, with the exception of screening.

Because of the basic similarities in the processing and operation of the various shrimp canning plants, it was decided to make a thorough study of one plant which would be considered typical. The typical data and results from this operation could then serve as a guide for applying the information gained to each of the similar processors.

Although some data on the characteristics of the wastewater of shrimp canning plants was found to be available, as mentioned in the preceding section, the volume of data was quite limited. A further objective of the study was to accumulate and add to the available data on this type of wastewater.

The following specific tasks were established as objectives in this study:

1. Characterize in a physical, chemical, and biological sense the wastewater from a typical shrimp canning plant.
2. Measure the wastewater stream flows from a typical shrimp canning plant.
3. Evaluate and recommend technical changes in the canning process operations to reduce wastewater flows.
4. Perform pilot scale studies on typical shrimp canning wastes in order to develop specific design and operating procedures for selected treatment

methods.

5. Determine the economics of various alternative procedures to capture and dispose of the solid wastes.

After selecting a typical plant (Robinson Canning Company, Inc., Westwego, Louisiana, shown in the report as Plant A), the study was conducted at this plant site during the summer and winter seasons of 1972 and during the summer of 1973. A portable laboratory was installed at the site, a portable pilot scale treatment facility was installed to treat a portion of the waste discharged from the canning plant, and study personnel monitored the plant operations.

The initial season was used to measure wastewater flows and to sample and analyze the waste streams. Volumes of water wasted from each process were measured by metering the source of water to the process and/or by measuring waste flow streams in channels. A continuous record of water consumption was kept during the period that this study was conducted.

The characteristics of the waste streams were established by multiple analyses during the period of the study. Also, waste flows from various other plants in the New Orleans area, in the lower Terrebonne Parish area of Louisiana and in the Biloxi area of Mississippi were sampled to compare to the "typical" plant waste discharge. Results are compared and discussed in succeeding sections of this report.

It was not possible to obtain the pilot plant until October, 1972, missing the first, summer season. The shortage of the shrimp supply to the typical plant during the fall of 1972 hindered the accomplishment of many pilot runs during that period. The preliminary jar testing, chemical selection, shakedown operations and general preparation was done during this time, however. During the summer 1973 season the pilot plant was operated as much as possible, varying operating conditions to permit pilot scale demonstration of chemical dosages, pH control, air ratio, recirculation ratio and other plant variables. Performance data was collected and analyzed, and is presented in later sections of this report.

The alternative procedures now used for capturing and disposing of solid wastes were reviewed at the typical plant and at other shrimp canning plants. Various types of screens were tested and evaluated for efficiency in the removal of settleable solids. Solid waste handling techniques in use and other available methods were reviewed.

The techniques and approach used in each objective or task of this study are more fully discussed in the subsequent sections of this report. All data developed are available from EPA in a separate Appendix.

SECTION VI

WASTEWATER SURVEYS

GENERAL

Shrimp canning wastewaters were characterized physically, chemically and biologically at six different plants in the Gulf Coast area. Most of the work was performed at Plant A (the location of the pilot plant studies). Wastewater surveys were performed a total of 18 days at this plant during the summer and fall 1972 canning seasons and the summer 1973 canning season. This plant was located in the New Orleans, Louisiana metropolitan area. An additional five days of surveys were performed at three other plants (Plants B, C and D) in the New Orleans area during the summer 1973 canning season. A one day survey was performed at a plant (Plant E) in the Houma, Louisiana area in the summer of 1973, and a three day survey was performed at a plant (Plant F) in the Biloxi, Mississippi area.

The objective of this work was to establish a typical wastewater characterization profile for the Gulf Coast shrimp canning industry. The characterization of each of the 22 shrimp canning plants was beyond the resources of this study; however, due to the similarity of process equipment used in the industry it was assumed that a well operated plant would produce a "typical" wastewater. A plant was chosen that would offer good facilities for pilot testing and be well established in order to ensure good production during the study periods. This was Plant A and most of the characterization effort was expended at this plant. The possibility existed that this plant was not typical so check surveys were performed at three other plants in the New Orleans area and one plant in each of the other principal shrimp canning areas; the Houma, Louisiana area (Bayou Grand Caillou) and the Biloxi, Mississippi area (Biloxi Bay and Mississippi Sound).

SURVEY METHODOLOGY

The wastewater survey at Plant A characterized all wastewater discharges and in-

ternal unit processes as to flow and physically, chemically and biologically.

Ten internal sample stations (See Figures 7 thru 10) were established at Plant A where composites were collected on each of the survey days. The stations were located so that all internal unit processes in the plant were characterized. Composite sampling techniques are included in Appendix B. A list of sample stations and locations follows:

Sample Station	Plant Process
1	Screened peeler and separator wastewater
2	Raw Peeler and Separator wastewater
3	Cleaner Flume Water
4	Separator Wastewater
5	Pre-Inspection Flume Water
6	Deveiner Wastewater
7	Blanch Tank Wastewater
8	Canning Room Floor Wash
9	Processing Room Floor Wash
11	Receiving Wash Wastewater

Three external sample stations were established and composites of wastewater discharge were collected on each of the survey days. Two separate discharges existed at Plant A. The main discharge served all the heavily polluted wastewater discharged from the plant and received the major sampling emphasis. A minor discharge (Sample Station 12) served only can cooling water discharges. The main discharge was further broken down into a process wastewater discharge (Sample Station 10) where a composite sample was collected during shrimp processing times only and a washdown wastewater discharge (Sample Station 10A) where a composite sample was collected during washdown times only. The breakdown of the main discharge into two samples was necessary because of an extreme variation of total process time from day to day. If a composite sample had been collected of the main discharge from start of process to the end of washdown on each day, the washdown discharge which was fairly uniform from day to day would have had a varying impact on the total discharge. Therefore, in order to compare daily discharges on a pollutant/product basis, a separation of this main discharge was necessary.

A "typical" process day was defined as eight hours of shrimp processing plus washdown. On days where this occurred at Plant A a total composite (Sample Station 10 T) was collected at the main discharge from start of process to the end of washdown. During the planning for this study the eight hour process day was thought to be typical and would occur most days. This, however, turned out to be wishful thinking because widely varying but usually short process times occurred (one to three hours), hence the necessity for separating the process and wash-

**Figure 7 PLANT A LAYOUT
WASTEWATER DRAINAGE SYSTEM**

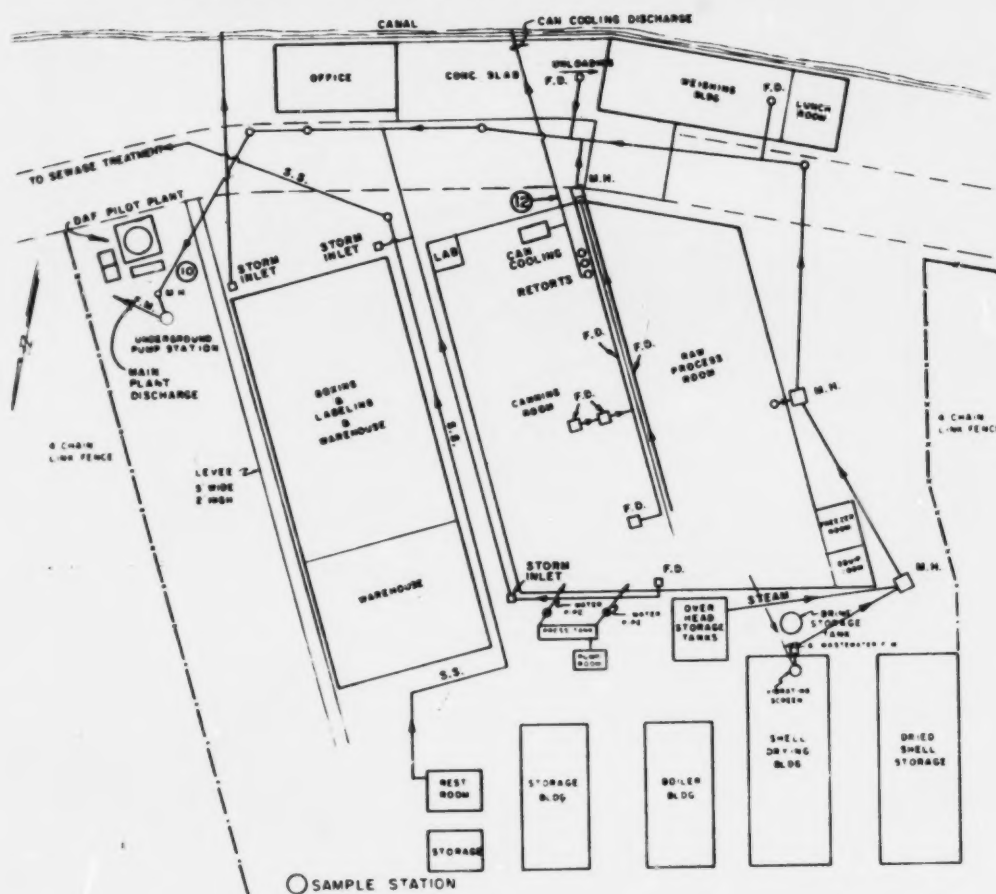


Figure 8 WASTEWATER SAMPLE STATIONS
WASTEWATER SURVEY
PLANT A
RAW SHRIMP PROCESSING

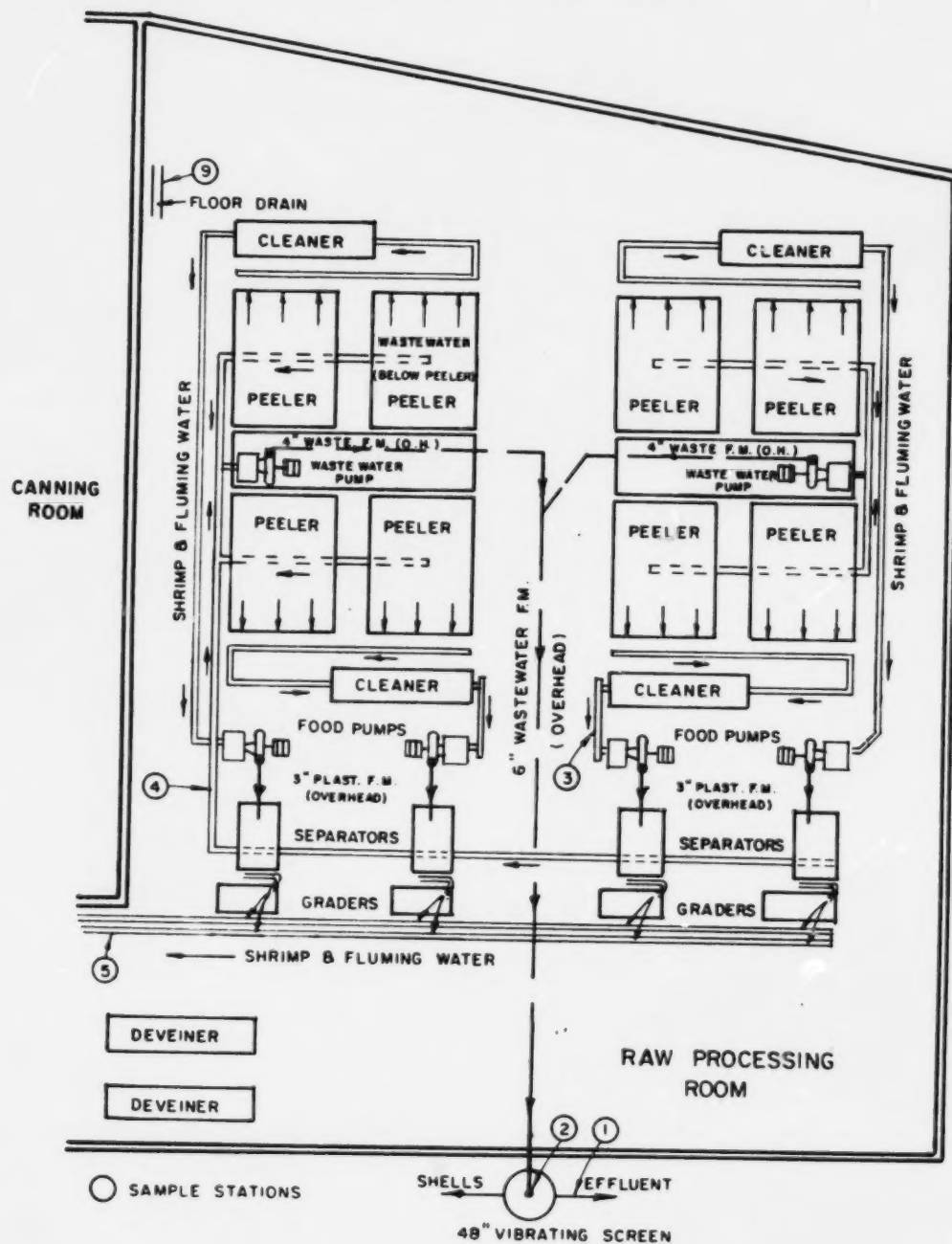


Figure 9 WASTEWATER SAMPLE STATIONS
WASTEWATER SURVEY
PLANT A
SHRIMP CANNING AREA

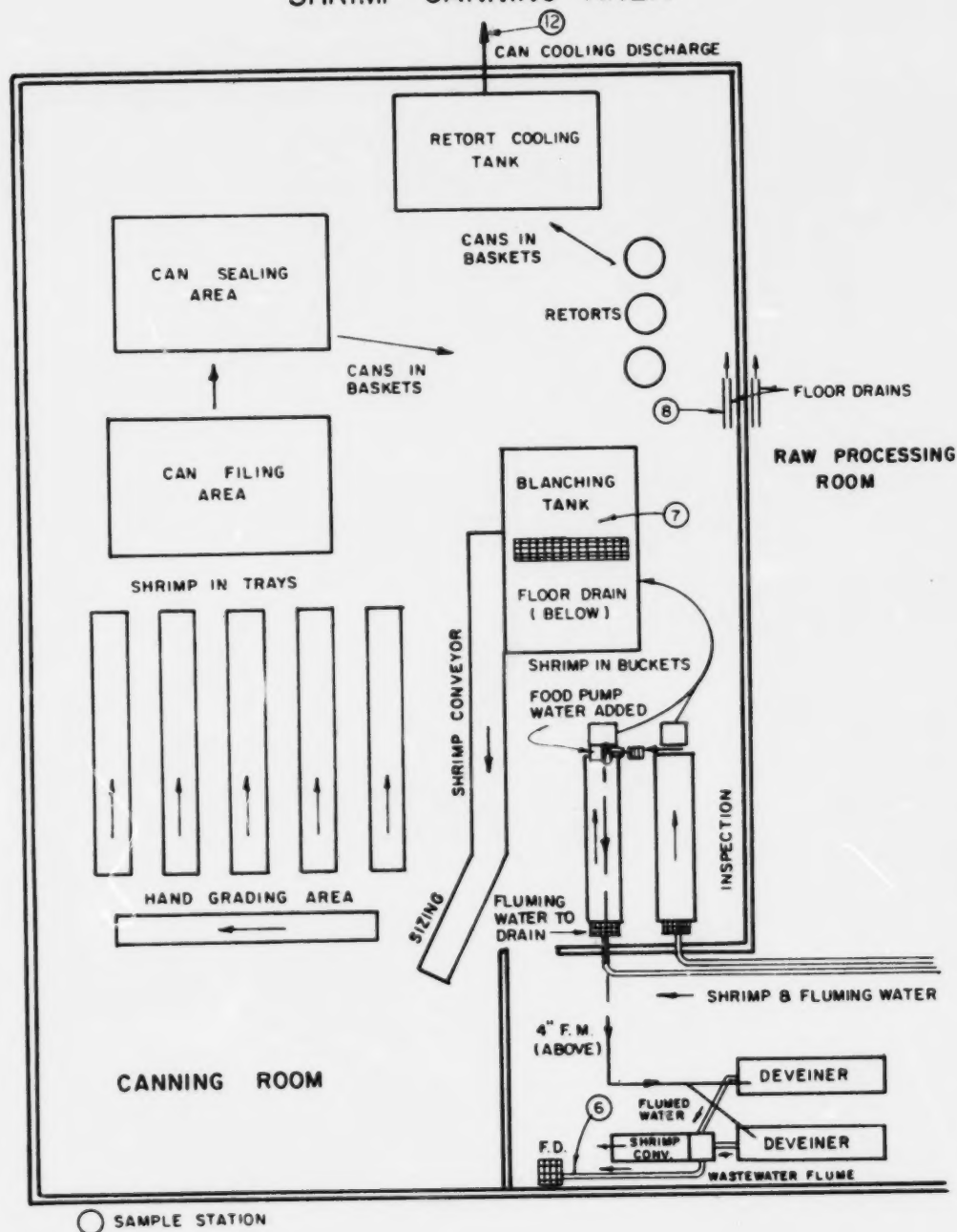
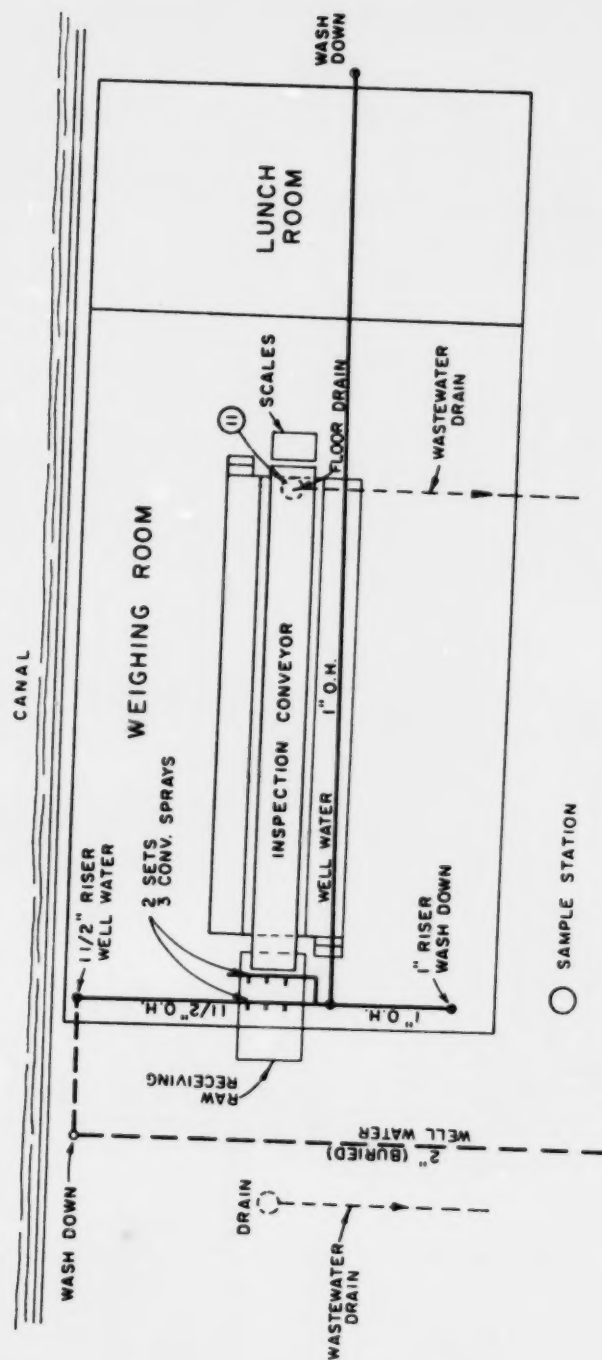


Figure 10 WASTEWATER SAMPLE STATIONS
WASTEWATER SURVEY
PLANT A



down samples. A list of discharge sample stations and locations follows:

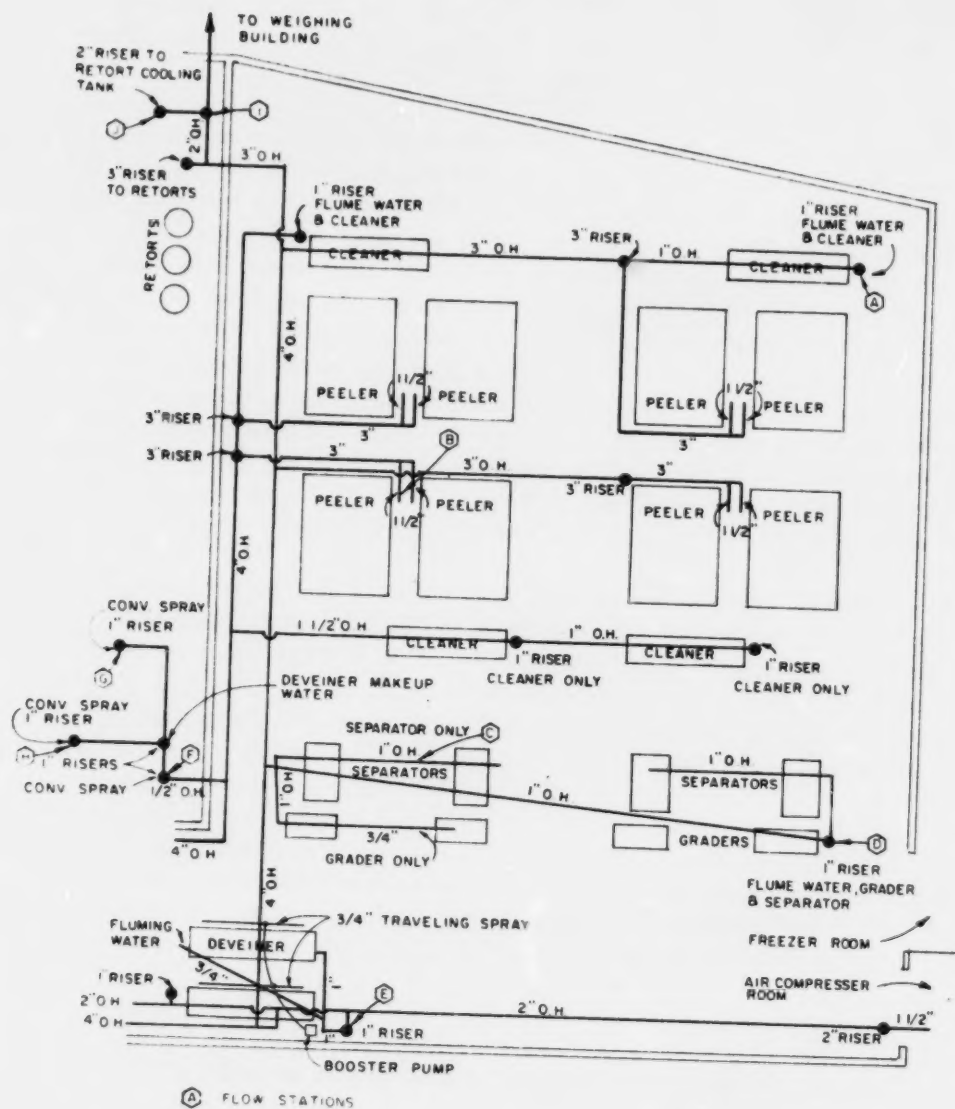
Sample Station	Plant Discharge
10	Main Discharge - Process Wastewater
10A	Main Discharge - Washdown Wastewater
10T	Main Discharge - Process and Washdown
12	Can Cooling Water Discharge

The wastewater flows, as in any plant, were difficult to measure. At Plant A several methods were necessary in order to determine the wastewater flows at the point of the sample station. Flow determinations at the sample stations were necessary in order to compute pollutant poundages; however, direct wastewater flow measurements at most of these locations were for the most part impractical. The wastewater flows were confined to gravity flumes, gravity pipes, or gravity collection hoppers discharging to floor drains or wastewater pumps. Any method of measuring flows at these locations would have been highly approximate and time consuming since an hourly measurement at each station was necessary in order to detect fluctuations and to compute material balances. The flow measurement method employed at most flow stations was to measure with a water meter the water entering the process. The water meters were read hourly during processing and washdown and the flows at the sample stations were computed.

The main discharge wastewater was measured by a different method because of economic constraints. The process water entered the plant from two sources; from a municipal treated supply which was metered and from a deep well which was not metered. The well water feed line required a 6 inch meter for flow measurement and expensive repiping work. This expense was beyond the capability of the project so an alternate main discharge flow measurement method was chosen which involved installing pressure gauges and time clocks on the main discharge pumping stations. The time clocks and pressure gauges were read hourly and the flow rate was then determined from the appropriate pump curves. This method of flow measurement was approximate, but a check was available for comparing with the sum of internal water uses contributing to this discharge. The water used and, therefore, the discharged wastewater for the can cooling was measured with a water meter.

Following is a listing of flow measurement stations (See Figure 11), the flow measurement method, the plant process measured and the process units at Plant A:

Figure II WATER FLOW STATIONS
WASTEWATER SURVEY
PLANT A



Flow Station	Process	Units Plant A	Method of Measurement
A	Flume make-up	2	Water Meter
B	Peeler	8	Water Meter
C	Separator	4	Water Meter
D	Flume make-up	1	Water Meter
E	Deveiner	1	Water Meter
F	Conveyer Spray	1	Water Meter
G	Pump Make-up	1	Water Meter
H	Conveyer Spray	3	Water Meter
I	Raw Receiving	1	Water Meter
J	Can Cooling	1	Water Meter
Pump Station	Main Wastewater Discharge	1	Time Clock-Pres. Gauge & Pump Curve

RESULTS AT PLANT A

Table 16 shows characterization results at Plant A in terms of pollutants (kg per 100kg raw shrimp processed). These computations were made in order that dilution water would not be a factor in comparing other plants to Plant A and also in comparing different processing days at Plant A. The first four columns give characteristics of internal plant processes. The last two columns give the combined plant discharge broken down into processing time only and washdown time only. The last two columns should be summed to obtain total combined plant discharge. Results indicate that approximately 5 kg BOD-5 are discharged as waste per 100 kg of raw shrimp processed.

Pollutant material balances were computed for Plant A on days where sufficient data existed. For each pollutant parameter the sum of the weights produced internally should equal the sum of the weights discharged. For the main plant discharge during the processing period internal pollutant weights were computed and compared to external discharged pollutant weights. The results are shown in Table 17. This was also computed for the washdown period, as shown in Table 18 and processing plus washdown in Table 19.

Table 17 shows the results of material balances of pollutants at Plant A during shrimp processing only. The composite wastewater samples were started when shrimp peeling started in the plant and the composite was completed when the unit operation tested, such as deveining, stopped. The internal wastes were the summation of wastes discharged at Station 1 (peeler and separator wastewater), Station 6 (deveiner wastewater), Station 7 (blanching wastewater), Station 11 (unloading and de-icing

Table 16. AVERAGE WASTEWATER CHARACTERIZATION
PLANT A
Values in kg/100 kg raw shrimp

Wastewater Parameter	Raw Peeler & Separator Station 2		Deveiner Station 6		Blanch Tank Station 7		Receiving & Raw Washing Station 11		Total Discharge Washdown Only Station 10A		Total Discharge Processing Only Station 10	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
BOD ₅	4.89	1.01	0.51	0.03	0.15	0.04	0.66		0.40	0.11	4.61	0.32
COD	10.80	1.74	1.08	0.27	0.30	0.08	0.87	0.24	1.64	0.47	8.14	0.05
O & G	2.91	1.74	0.15		0.27		0.19	0.06			3.58	1.63
Tot. N (as N)	0.80	0.95	0.10	0.07			0.02		0.014	0.007	0.19	0.12
Tot. Alk.	2.05	0.46	0.11	0.02	0.03	0.01	0.22	0.12	0.82	0.38	2.22	0.31
Ortho P (as P)	0.25	0.09	0.03	0.01	0.01	0.01	0.013	0.003	0.07	0.05	0.23	0.03
TS	10.64	2.66	0.99	0.24	3.51	1.00	1.04	0.36	6.35	2.10	15.22	2.50
TVS	7.12	2.33	0.75	0.19	0.84	0.49	0.59	0.26	1.95	1.23	6.38	2.87
TSS	2.63	1.32	0.45	0.22	0.19	0.13	0.25	0.19	0.34	0.29	0.83	0.49
VSS	2.43	1.34	0.40	0.26	0.09	0.11	0.12	0.06	0.33	0.27	0.61	0.53
$\bar{x}$ = Mean												
s = Standard Deviation												

Table 17. POLLUTANT MATERIAL BALANCES
DURING PROCESSING AT PLANT A

Date Sampled	Parameter	Weight (kg)							External Station 10	External Sum of Internals
		Internal								
		Station 1	Station 6	Station 7	Station 11	Misc.	Sum			
7/13/72	COD	1,151	128	52	124	150	1,605	1,351	0.84	
6/29/72	Tot. Alk.	313	21	6	40	38	418	399	0.95	
7/15/72	Tot. Alk.	182	14	3	12	21	232	239	1.03	
7/7/72	Ortho P as P	31	10	2	3	5	51	48	0.95	
7/15/72	Ortho P as P	26	4	2	2	4	38	25	0.66	
6/29/72	TS ^a	1,633	164	734	196	273	3,000	2,884	0.96	
7/13/72	TS ^a	1,629	125	805	157	272	2,988	2,678	0.90	
6/29/72	TVS ^b	1,130	134	326	124	171	1,885	1,181	0.63	
7/13/72	TVS ^b	1,022	97	85	96	130	1,430	1,111	0.78	
7/13/72	TSS ^c	149	70	9	27	25	280	237	0.84	
^a Total Solids										
^b Total Volatile Solids										
^c Total Suspended Solids										

wastewater) and miscellaneous discharges such as fluming water and conveyer spray water. The external wastes were the total combined plant discharge wastes at Station 10. For a material balance the sum of the internals should be equal to the external.

On July 13, 1972 sufficient data was collected and analyzed in order to compute a material balance for COD. The balance had approximately a 16% error. The error was due to cumulative errors in sampling, flow measurement and analysis in the laboratory. Material balance computations for other parameters had a range of errors from 3% to 37%.

Table 18 shows material balance computations during washdown at Plant A. For this period composite wastewater samples were started at Sample Station 9 when washdown started in the raw process section of Plant A and the composite was completed when washdown in this section of the plant was completed. The same procedure was used for Sample Station 8 in the canning section of the plant. During this same time a total composite which included washdown from both sections of the plant was collected at Sample Station 10A.

The material balances shown in Table 18 indicate poor correlation for all parameters with the exception of solids. These results were expected, however, because of the extreme difficulty in obtaining representative samples during washdown. For example, when the blanch tanks were dumped and cleaned an extremely concentrated slug of water was released. The floor washings were also quite variable. A great deal of meat fragments accumulated on the floor during the washdown of the equipment. When this material was washed from the floor to the drain flumes representative samples were difficult to obtain.

Table 19 shows material balance computations for a total plant day, including processing and washdown. The external discharge station 10 T was only composited on days when the shrimp supply allowed the plant to process approximately 8 hours. The errors in material balances varied from approximately 62% to 33%. These results were inferior to "process only" balances because the washdown period was included in the composites. As previously discussed, obtaining representative composite samples of washdown water was most difficult.

COMPARISON OF PLANT A TO OTHER PLANTS

A comparison of Plant A discharged pollutants to five other Gulf Coast shrimp canning plants is shown in Table 20. The comparison was made on a kg pollutants/100 kg raw shrimp basis. For BOD-5, Plant A was the lowest of 4 plants that were tested. Plant A was only slightly lower than Plants D and E, but considerably

Table 18. POLLUTANT MATERIAL BALANCES
DURING WASHDOWN AT PLANT A

Date Sampled	Parameter	Weight (kg)				External Sum of Internals
		Internal			External Station 10A	
		Station 8	Station 9	Sum		
7/ 6/72	BOD ₅	6.3	3.2	9.5	73.4	7.73
7/13/72	COD	131.3	46.2	177.5	293.5	1.65
7/13/72	Tot. N as N	1.8	0.9	2.7	1.4	0.52
7/15/72	Tot. N as N	0.5	0.5	1.0	1.8	1.80
6/29/72	Tot. Alk.	2.3	4.1	6.4	68.0	10.63
7/ 6/72	Tot. Alk.	28.1	31.3	59.4	88.8	1.49
7/13/72	Tot. Alk.	77.5	58.0	135.5	182.0	1.34
7/15/72	Tot. Alk.	38.1	35.3	73.4	116.9	1.59
7/ 6/72	Ortho Pas P	0.5	0	0.5	6.3	12.60
7/13/72	Ortho Pas P	2.7	0.9	3.6	20.8	5.78
7/15/72	Ortho Pas P	1.8	0.5	2.3	6.3	2.74

Table 18 (continued). POLLUTANT MATERIAL BALANCES
DURING WASHDOWN AT PLANT A

Date Sampled	Parameter	Weight (kg)					External Sum of Internals
		Internal			Sum	External Station 10A	
		Station 8	Station 9	Station 10A			
7/ 6/72	TS ^a	105	529	635	933	1.47	
7/15/72	TS ^a	164	143	307	366	1.19	
7/ 6/72	TVS ^b	58	417	475	324	0.68	
7/15/72	TVS ^b	50	17	67	52	0.78	
7/15/72	TSS ^c	19	4	23	59	2.57	
^a Total Solids		^b Total Volatile Solids		^c Total Suspended Solids			

Table 19. POLLUTANT MATERIAL BALANCES
DURING PROCESSING PLUS WASHDOWN
PLANT A

Date Sampled	Parameter	Weight (kg)								External Station 10T	External Sum of Internals
		Internal									
		Station 1	Station 6	Station 7	Station 8	Station 9	Station 11	Misc.	Sum		
6/30/72	BOD ₅	1,755	185	42	59	21	230	229	2,517	1,420	0.56
7/10/72	COD	2,991	439	71	57	10	227	392	4,187	3,529	0.84
6/30/72	Tot. Alk.	611	45	8	84	134	125	101	1,108	827	0.75
7/10/72	TS ^a	3,823	450	1,301	124	43	255	600	6,596	8,788	1.33
7/10/72	TVS ^b	2,640	351	347	53	1	98	349	3,840	2,590	0.67
7/10/72	TSS ^c	503	117	64	35	35	39	79	872	329	0.38
^a Total Solids		^b Total Volatile Solids			^c Total Suspended Solids						

lower than Plant F. For COD, Plant A again was the lowest of six plants tested at 8.14 kg COD/100 kg shrimp. Plant C was in the same range as Plant A at 8.27 kg COD/100 kg shrimp; however, Plants B, D, E and F all had considerably larger discharges with Plant F at 23.65 kg COD/100 kg shrimp. Total solids discharged shows Plant C the lowest and again Plant F the highest with Plant A approximately mid-way. Total suspended solids discharged shows a large amount of scatter in the testing with Plant A again having the lowest discharge and Plant F the highest.

Plants A, B, C and D all screen their peeler wastewaters, but Plants E and F do not. This partially accounts for the larger discharges at Plants E and F. Deviations could have also occurred because different labs analyzed the wastes from each of the Plants E, F and remaining 4 plants. Comparing only Plants A, B C and D and considering a 20 to 30% scatter in the data, it appears Plant A has a slightly lower but similar discharge to the other three plants.

Table 21 shows peeler wastewater pollutants compared at five plants. The values shown are raw peeler wastes prior to screening. The peeler wastewaters at Plant A appear very similar to the other plants with the exception of Plant E. Again the analysis of the wastewaters at Plant E was performed at a different lab than the other four plants. Total suspended solids at Plant A, however, was much lower than at the other plants. This is a significant difference and it is not known whether the cause was a sampling and testing error or a processing difference at Plant A. Total solids showed less scatter and were within the expected deviation.

Table 22 compares washdown at Plants A and C. Considering the difficulties in obtaining representative washdown composites, the values are extremely close and the two tested plants appear very similar.

Table 23 compares deveiner wastewaters at Plants A and D. Plant A has a slightly higher discharge than Plant D, but within the expected deviation.

In summary, the comparison data showed considerable scatter, but did indicate that Plant A had a similar discharge to the other tested plants. The code identification for the tested plants is shown in Table 24.

Table 20. COMPARISON OF COMPOSITE DISCHARGE
WASTEWATER POLLUTANTS
Processing Time Only

Plant	Quantity kg/100 kg Raw Shrimp			
	BOD-5	COD	Total Solids	Total Susp. Solids
A ^a	4.61	8.14	15.22	0.83
B ^b		16.16	12.25	3.67
C ^c		8.27	8.50	2.19
D ^d	5.27	12.60	11.95	4.39
E ^e	5.36	19.28	29.14	1.64
F ^f	13.90	23.65	32.35	9.20

- a average of 5 values - screened peeler wastes
- b average of 2 values - screened peeler wastes
- c one value - screened peeler wastes
- d average of 2 values - screened peeler wastes
- e one value - raw peeler wastes
- f average of 3 values - raw peeler wastes

Table 21. COMPARISON OF RAW PEELER
WASTEWATER POLLUTANTS

Plant	Quantity kg/100kg Raw Shrimp			
	BOD-5	COD	Total Solids	Total Suspended Solids
A ^a	4.22	7.38	8.85	1.65
B ^b		9.21	7.49	3.20
C ^c		6.67	10.13	5.51
D ^d	4.71	8.75	10.90	4.63
E ^e	3.26	16.15	24.01	3.05

^a - average of 6 values, ^b - one value, ^c - one value, ^d - one value
^e - one value

Table 22. COMPARISON OF WASHDOWN
WASTEWATER POLLUTANTS

Parameter	Quantity kg/100 kg Raw Shrimp	
	Plant A	Plant C
COD	1.64	1.15
Ortho Phosphate	0.07	0.03
Total Solids	6.35	6.18
Total Suspended Solids	0.34	0.27

Table 23. COMPARISON OF DEVEINER
WASTEWATER POLLUTANTS

Parameter	Quantity kg/100 kg Raw Shrimp	
	Plant A	Plant D
BOD-5	0.51	0.24
COD	1.08	0.80
Ortho Phosphate	0.03	0.02
Total Solids	0.99	1.31
Total Suspended Solids	0.45	0.32

Table 24. SHRIMP CANNING PLANTS
Code Identification

Plant	Location	Code
Robinson Canning Company	Westwego, La.	A
Cutcher Canning Company	Westwego, La.	B
Reuther Seafood Company	New Orleans, La.	C
Southern Shellfish Company	Harvey, La.	D
Calvin Authement Canning Plant	Dulac, La.	E
DeJean Packing Company	Biloxi, Miss.	F

SECTION VII

BENCH SCALE STUDIES

GENERAL

Bench scale studies with a flotation bomb and jar tests were performed in order to determine treatability by the DAF process. Gravity drainage of DAF skimmings was also performed in order to evaluate the effect of chemical dosages on the nature of the skimmings and to evaluate further concentration by gravity thickening.

Buchner funnel tests on the DAF plant sludge were performed in order to evaluate the feasibility of vacuum filtration.

JAR TESTS

Jar tests were performed only as a method for screening coagulants and coagulant aides in order to have an effective chemical system prior to the start of DAF pilot plant testing. Jar tests are nothing more than a method of optimizing a coagulant system. The methods used for this study are explained in Appendix A. The results of jar tests, however, divulged considerable basic information about the wastewater, such as the relative size of the particles in the wastewater, as discussed in Section IV.

The treatability of shrimp canning wastewater by the DAF process was first evaluated in the fall of 1972 by conventional jar tests. Selected combinations of coagulants and polyelectrolytes were tested in order to qualitatively determine a workable chemical combination. The composite main discharge at Plant A was tested with a variety of coagulants and coagulant aides. The following chemicals were tried by using all reasonable combinations and a wide range of dosages:

pH Control

Sulfuric Acid

Caustic Soda

Water Conditioners

Sodium Carbonate
Zinc Sulfate

Coagulants

Aluminum Sulfate
Ferric Sulfate
Clay
Magnifloc 503C

Coagulant Aides

Betz 1130
Magnifloc 835A
Magnifloc 837
Magnifloc 905N
Magnifloc E323

The best floc was obtained with an acid, alum (aluminum sulfate), and magnifloc 835A combination. Alum and acid alone formed a light, fluffy, slow settling floc. When the Magnifloc 835 A was added the floc formed much faster, was much larger, tighter and settled better. None of the other coagulant aides in the list above performed as well as Magnifloc 835 A. No success was obtained by substituting a polymer or clay for alum. Good settling was obtained with alum dosages between 75 and 150 mg/l. Zinc sulfate and sodium carbonate conditioning seemed to have no effect on the settleability. The raw water at Plant A did contain a fairly high alkalinity, however, so water conditioning may be necessary at other plant locations. Using NaOH for pH adjustment when using alum and polymer was definitely inferior to acid pH adjustment. Good results were obtained with pH values between 4.8 and 5.2.

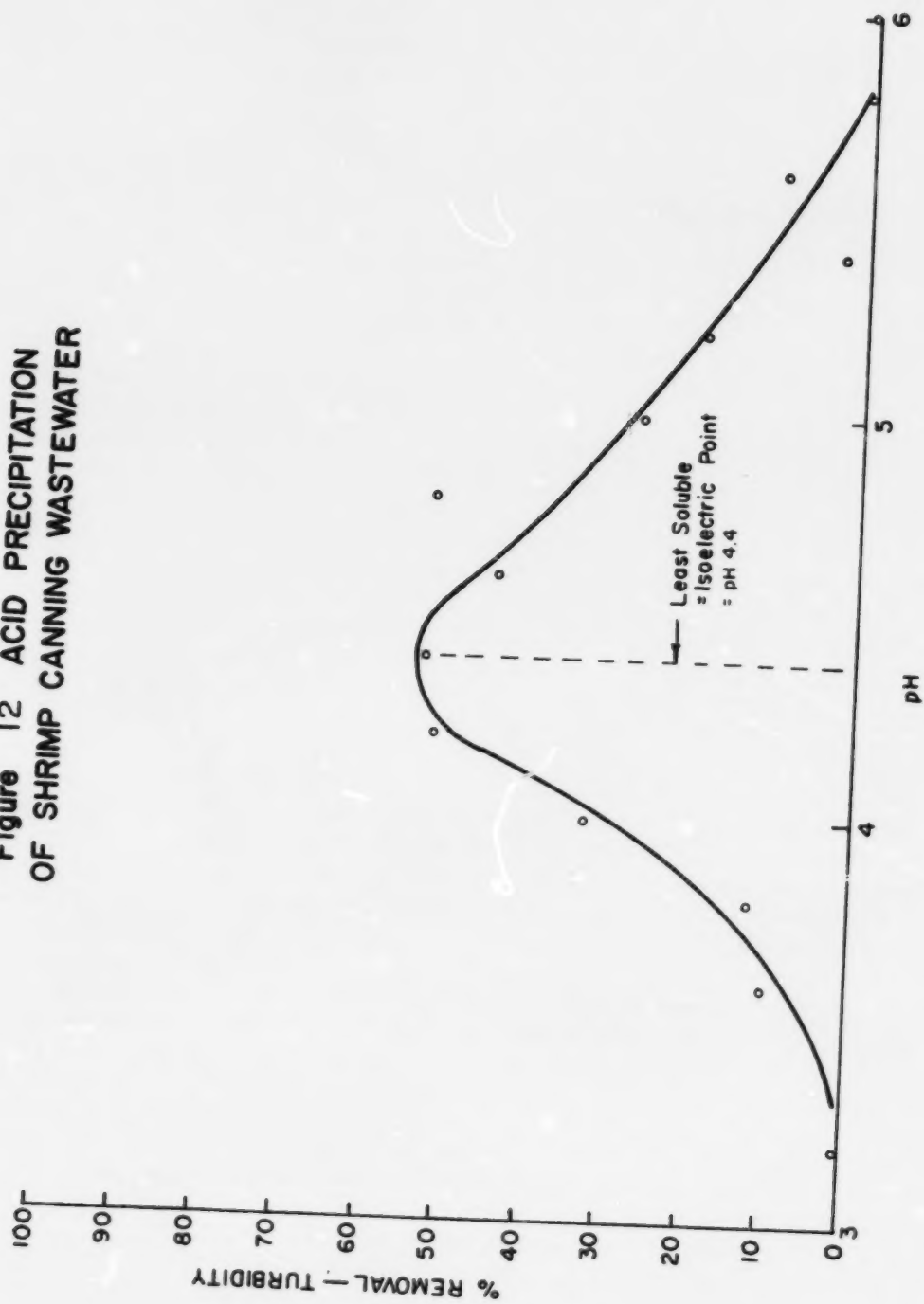
Figure 12 shows the results of H_2SO_4 titration on the raw shrimp canning wastewater. A regular jar test was performed by adjusting a sample to a desired pH, rapid mixing, allowing the sample to settle and then measuring the turbidity of the supernatant. The titration curve shows protein precipitation occurring only in a narrow pH range with maximum efficiency at about pH 4.4. From this data the isoelectric point was assumed to be pH 4.4.

The best chemical coagulant combination found in the jar testing was extremely efficient at optimum pH values stated above. However, since the isoelectric point of protein was pH 4, protein precipitation and protein removal at pH 5.0 was below maximum efficiency.

Many trial runs were made with various chemical combinations to try to eliminate alum as the primary coagulant. It was believed at this stage of the project that elimination of alum would greatly simplify sludge treatment and would increase the value of any by-product. Little success was achieved for these efforts. It appeared that alum would be required as the primary coagulant.

As described in Section VIII, Pilot Plant Studies, the chemical combinations dev-

**Figure 12 ACID PRECIPITATION
OF SHRIMP CANNING WASTEWATER**



eloped in the above described tests were used in the first pilot plant phase. An excellent correlation was obtained between the pilot plant results and the jar tests.

AIR FLOTATION BOMB

Prior to the start of the second pilot plant phase during the summer of 1973 a more thorough evaluation of chemical dosages was believed to be warranted. With the chemicals and dosages used in the first phase studies, an effluent barrier of about 1000 mg/l of COD developed that appeared impossible to break through. It was believed a completely different combination of chemicals could be found that could possibly give much better results. Information about the skimmings was also desirable. This could not be obtained from jar tests so a bench scale air flotation bomb was used for further testing. Additional jar tests were also performed for correlation.

Figure 13 shows the bench scale air flotation bomb used. The operational procedure used in these tests is explained in Appendix A. The air flotation bomb utilizes the dissolved air flotation (DAF) method for producing a bubble for floc flotation.

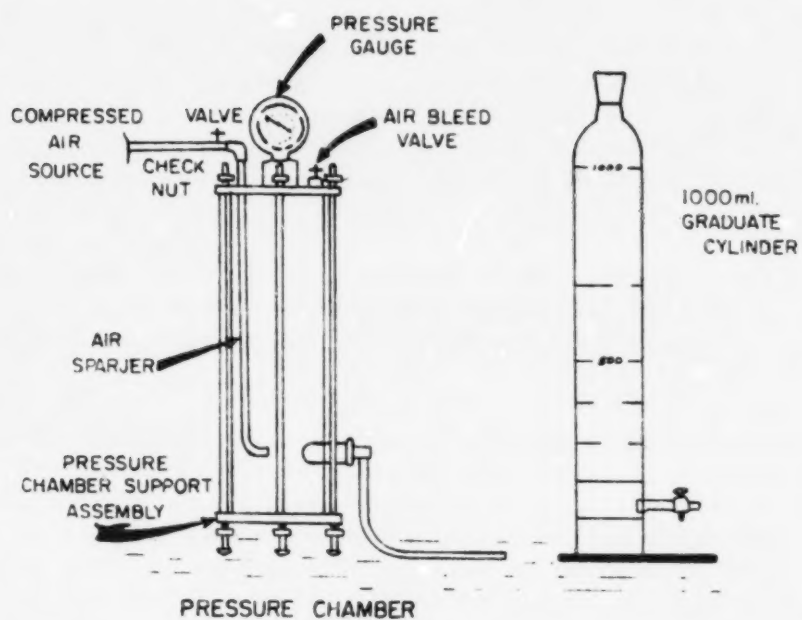
With the pressure bomb combinations of coagulants and polyelectrolytes were tested to determine optimum pH and dosages. System performance was primarily based on effluent quality as measured by total organic carbon (TOC). The effects of various dilution rates, direct versus pressurized recycle, variation in operating pressure, and alum efficiency at increased alkalinity were also investigated. Inherent in this study was, of course, a comparison of bench scale versus pilot plant performance.

The first pilot plant phase had determined that pH was an extremely important variable in DAF treatment of shrimp canning wastewater. The wastewater had a high concentration of protein with an isoelectric point of 4.4. The pilot plant, however, performed rather poorly at pH 4.4. This was due to the inactivity of the alum coagulant. An optimization of pH was required with each coagulant used.

The results of the jar testing and air flotation bomb testing for this period are included in a supplementary appendix available from EPA. A summary of the results and the investigator's conclusions are as follows:

1. The optimal pH as obtained by jar tests and prototype performance was pH 5.0, closely corresponding to the isoelectric point of the protein present,

**Figure 13 BENCH SCALE FLOTATION BOMB
FROM ECKENFELDER**



which was pH 4.4. At pH 5.0 a weak floc formation commenced without coagulant addition.

2. The most effective combination of chemicals for successful flotation operation consisted of alum and Magnifloc 835 A polymer at respective dosages of approximately 100 mg/l and 2 mg/l. While jar tests results indicated that alum dosages could be substantially reduced and possibly eliminated, flotation experience required alum to provide necessary floc size and strength.
3. Increasing the alkalinity for the alum runs did not appreciably affect system performance.
4. For the alum and Magnifloc 835 A runs, the jar tests gave comparable results (on a TOC removal basis) to the flotation bomb. The jar test, therefore, was used as a screening device for other coagulant and polymer combinations. Little information concerning floc strengths, however, was obtainable and good results with the jar tests did not imply equally good results with the flotation bomb.
5. It was observed that system performance could be correlated to color content - the clearer the effluent, the better the quality in terms of TOC.
6. Results indicate that precipitation by coagulation, flocculation, and sedimentation could provide a feasible alternative to dissolved air flotation (perhaps without alum addition).
7. Varying dilution rates for direct pressurization did not affect system performance appreciably.
8. A very clear effluent and dense float solids concentration was observed when pressurized recycle was employed with the bench-scale flotation device.
9. Variation in operational pressure of the dissolved air flotation bomb from 30 to 60 psi only improved TOC removals from 27% to 30%.
10. Bench-scale testing can satisfactorily simulate pilot plant performance based on effluent quality as measured by total organic carbon. Laboratory TOC removals from jar tests and the flotation bomb (when using alum and Magnifloc 835 A polymer) averaged 34% and 29% respectively. A study at the plant site on a fresh sample, however, yielded a reduc-

tion in TOC of 66% which was very near the average pilot plant performance of 61%. Thus it appears that for the shrimp wastewater, a fraction of the colloidal TOC solubilized or protein ammonified during shipment to the laboratory. It is therefore necessary that future bench-scale testing be conducted on site for absolute numerical comparisons of pilot plant or prototype results. In the completed study, however, successful screening of coagulants and flocculants was accomplished by the methodology employed.

11. Chemical precipitation or dissolved air flotation offers effective removal of organic constituents from shrimp cannery wastewaters with the possibility of protein recovery.

SLUDGE DRAINAGE

During most of the pilot plant DAF runs, a sludge drainability test in a 1000 ml graduated cylinder was performed on the sludge skimmings. Information about the drainage rate as a function of the DAF plant operating variables was desired. It was hypothesized the drainage rate would be a function of the air/solids ratio and the coagulant chemicals used with the DAF plant. The bench tests would indicate if gravity drainage would be feasible as a sludge concentration operation on a prototype scale.

Figures 14 through 21 show the results of drainage tests during the Fall 1972 pilot plant phase and the Summer 1973 pilot plant phase. The drainage rates in ml/minute was computed for the straight line segment of the curve in order to quantitatively compare the runs. The shape of all the curves are generally the same except the ones shown on Figures 14 and 15. These tests were the first done and, as can be seen, were prematurely ended. The other curves show a fast drainage linear drainage rate for about one hour; then a drastically decreased drainage rate for about two hours; then another fast linear rate for about two hours; then an abrupt leveling off (Figure 18).

It was hypothesized prior to the drainage studies that alum concentration would have a very large effect on the drainage rate. Alum floc is highly hydrated and it was believed that high concentrations of alum would hold water in the sludge and retard drainage. The drainage studies do indicate a relationship between drainage rate and alum feed concentration. For example the drainage studies shown in Figures 18 and 19 had the same operating conditions with only a slight difference in alum concentration and the curves are very similar with the drainage rates being almost identical. However, comparing Figures 16 and 19 where alum concentrations are in a 2:1 ratio the curves indicate a much faster initial drainage

Figure 14 SLUDGE DRAINAGE
DAF RUN 5P
Fall, 1972

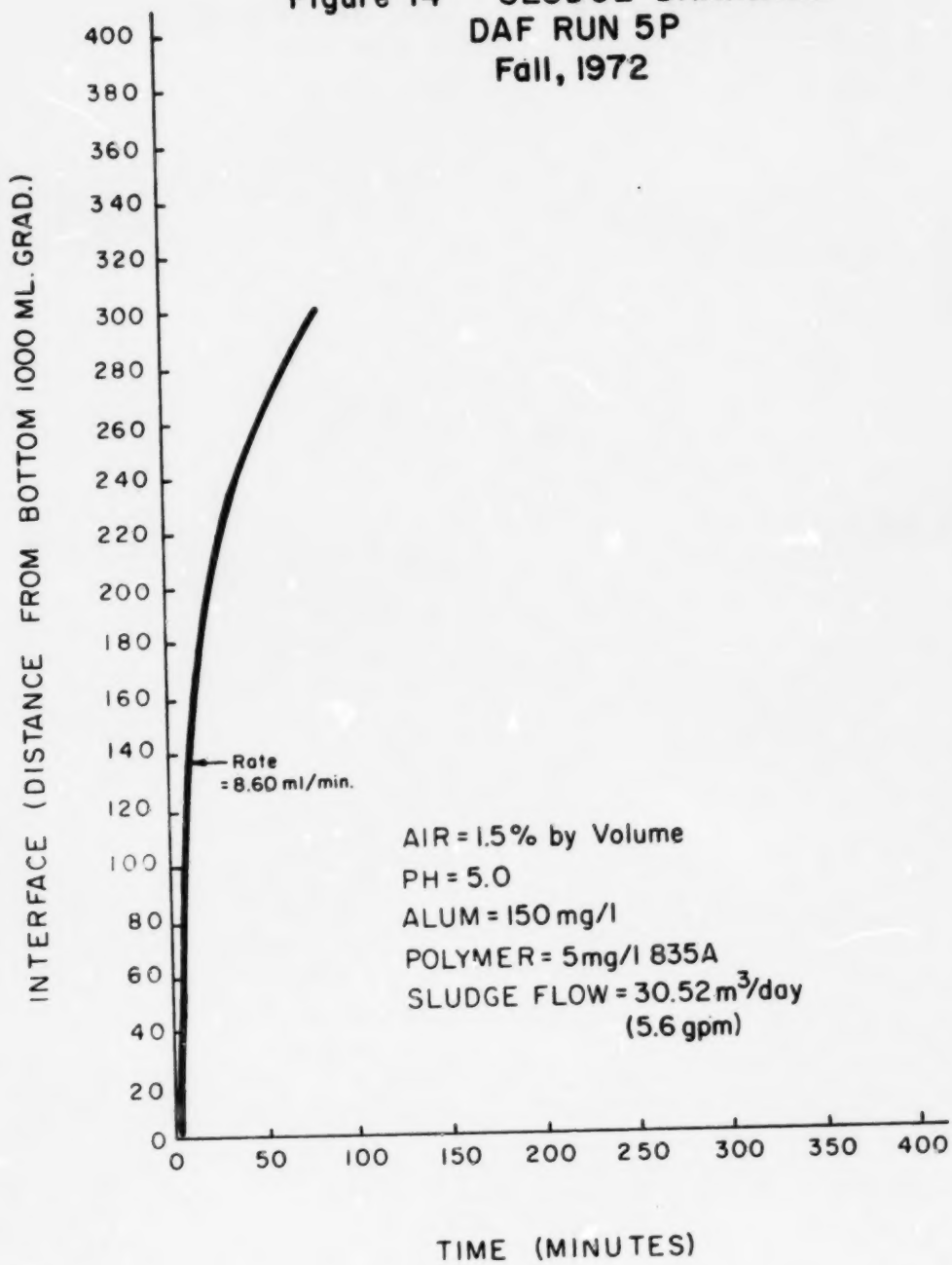


Figure 15 SLUDGE DRAINAGE
DAF RUN 12P
Fall, 1972

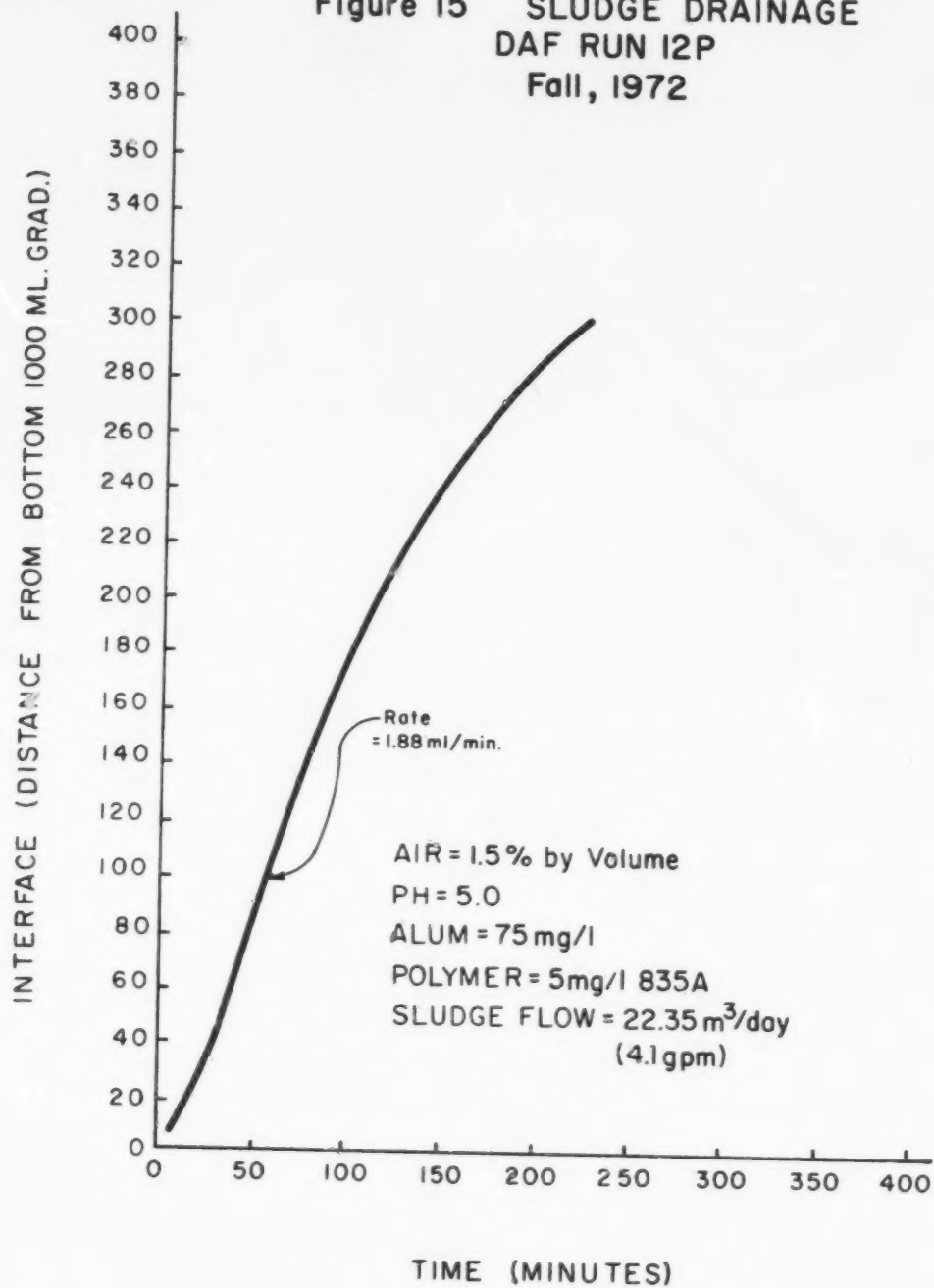


Figure 16 SLUDGE DRAINAGE
DAF RUN 5
Summer, 1973

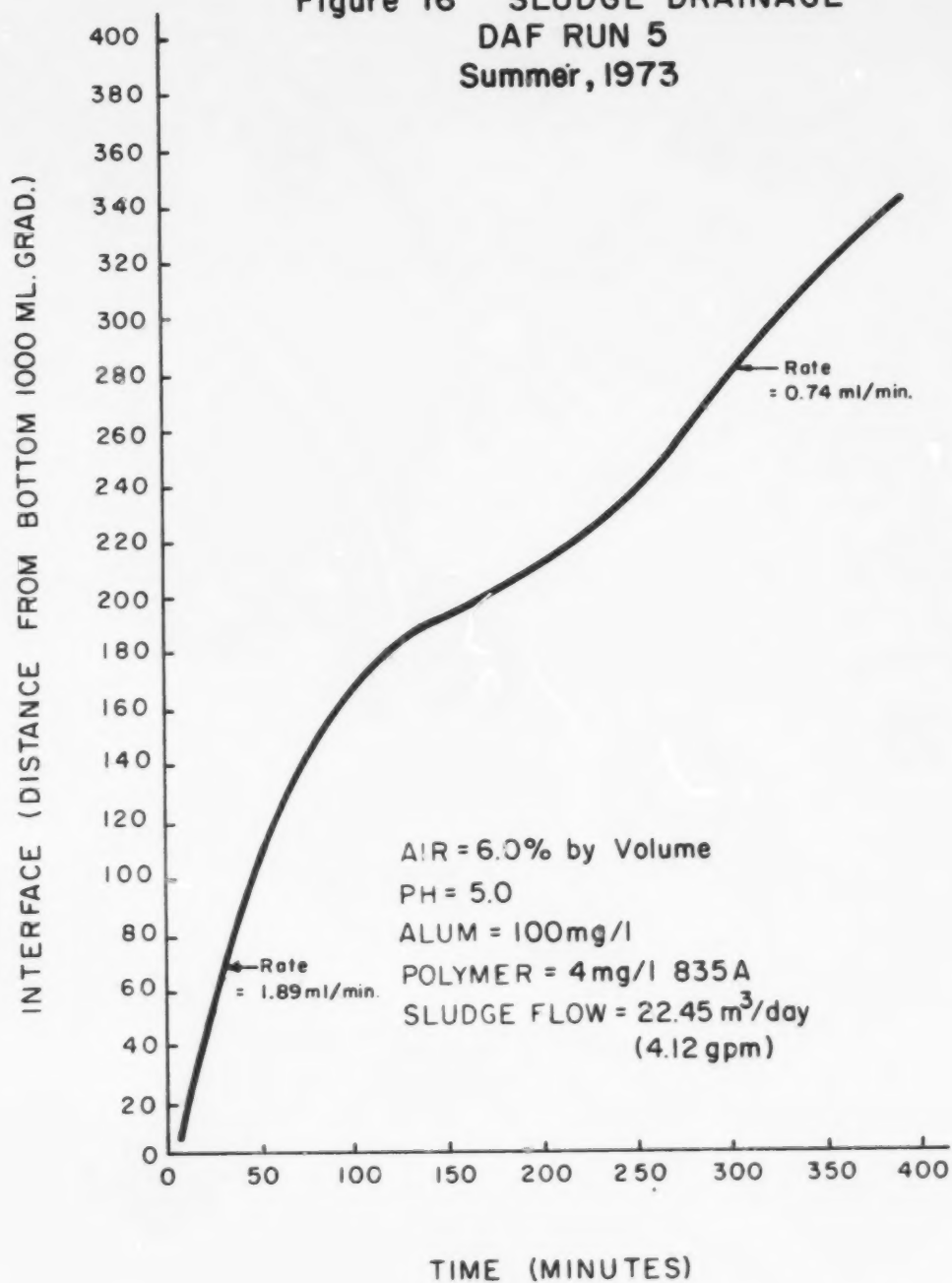


Figure 17 SLUDGE DRAINAGE
DAF RUN 8
Summer, 1973

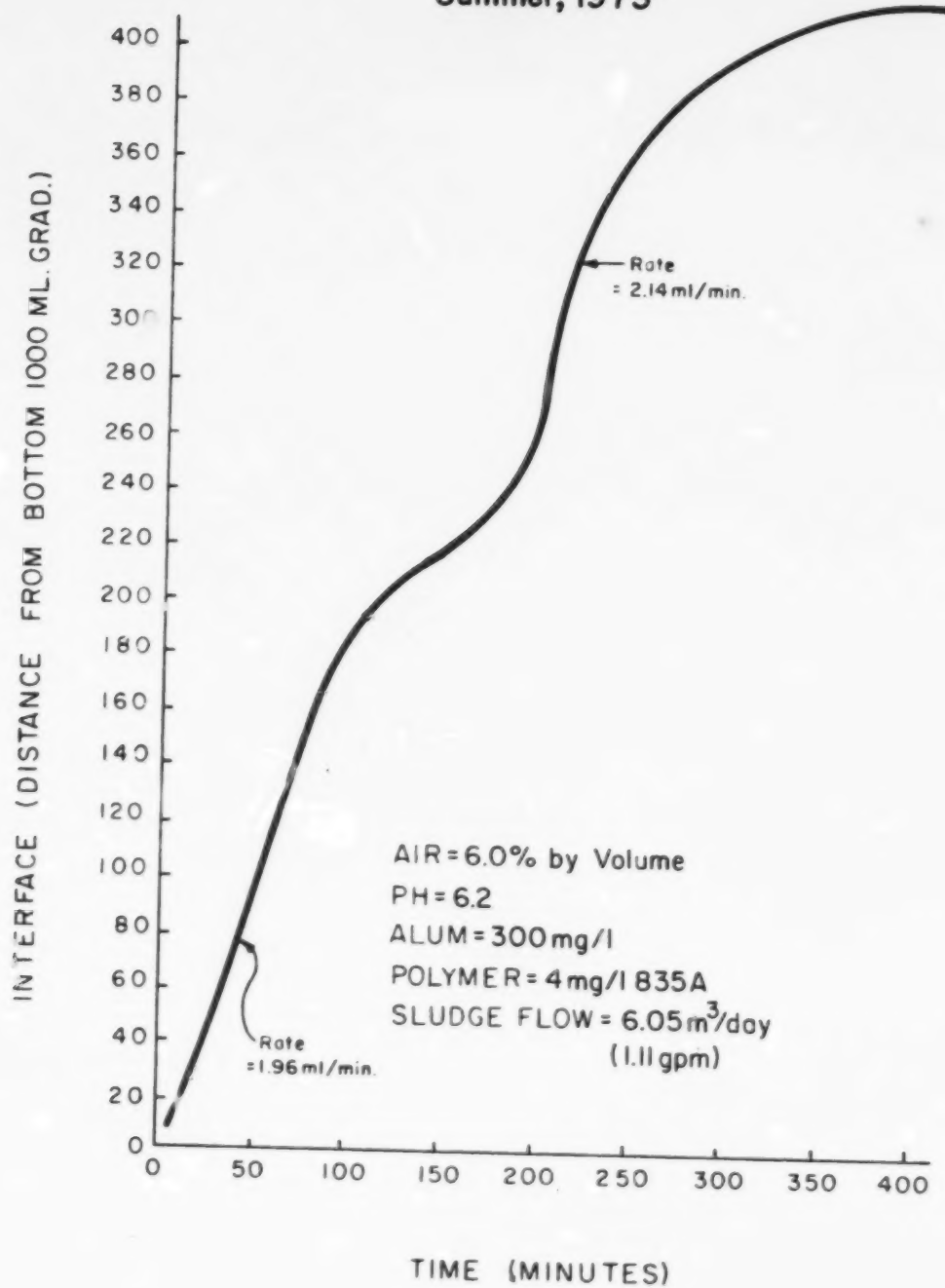


Figure 18 SLUDGE DRAINAGE
DAF RUN 12
Summer, 1973

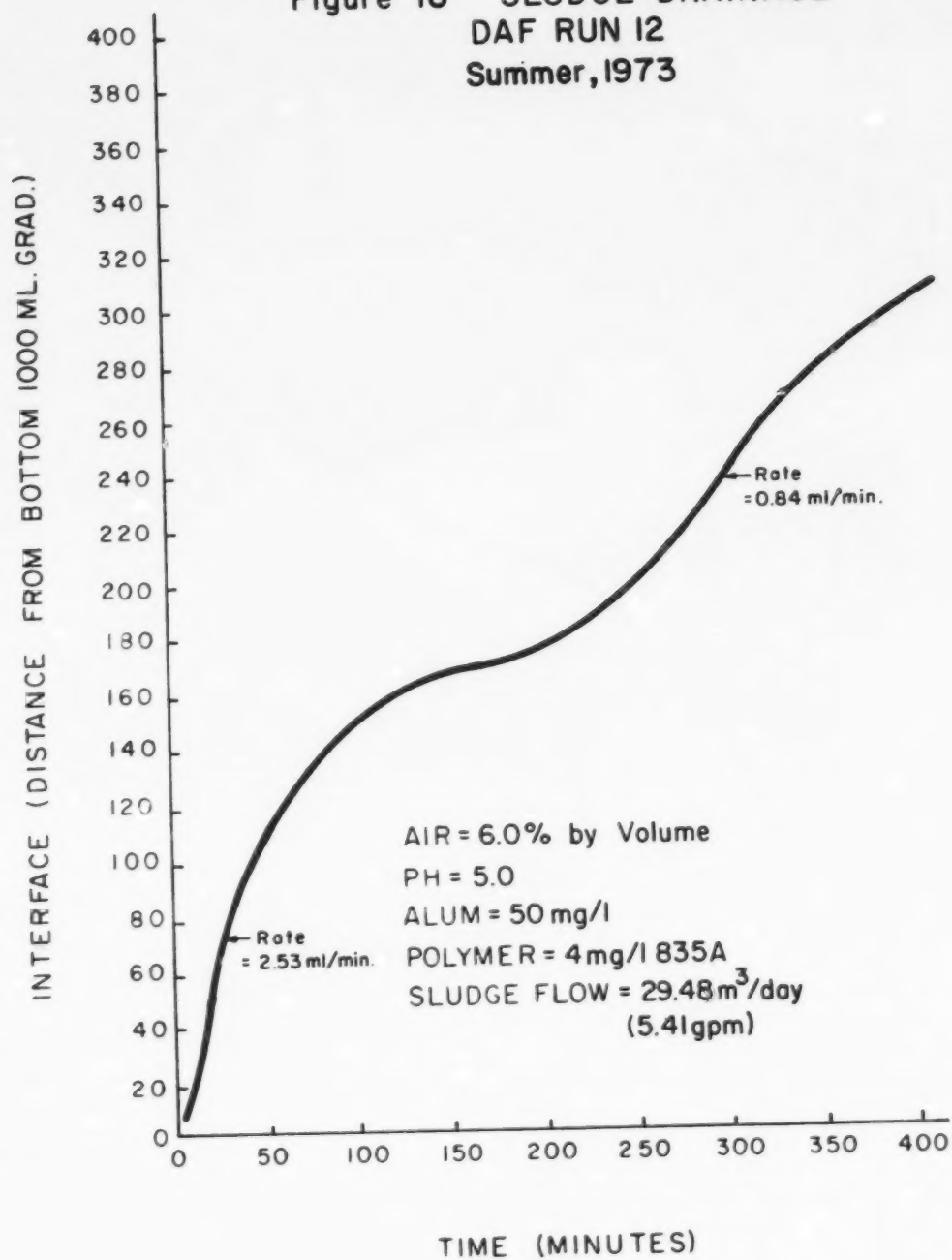


Figure 19 SLUDGE DRAINAGE
DAF RUN 13
Summer, 1973

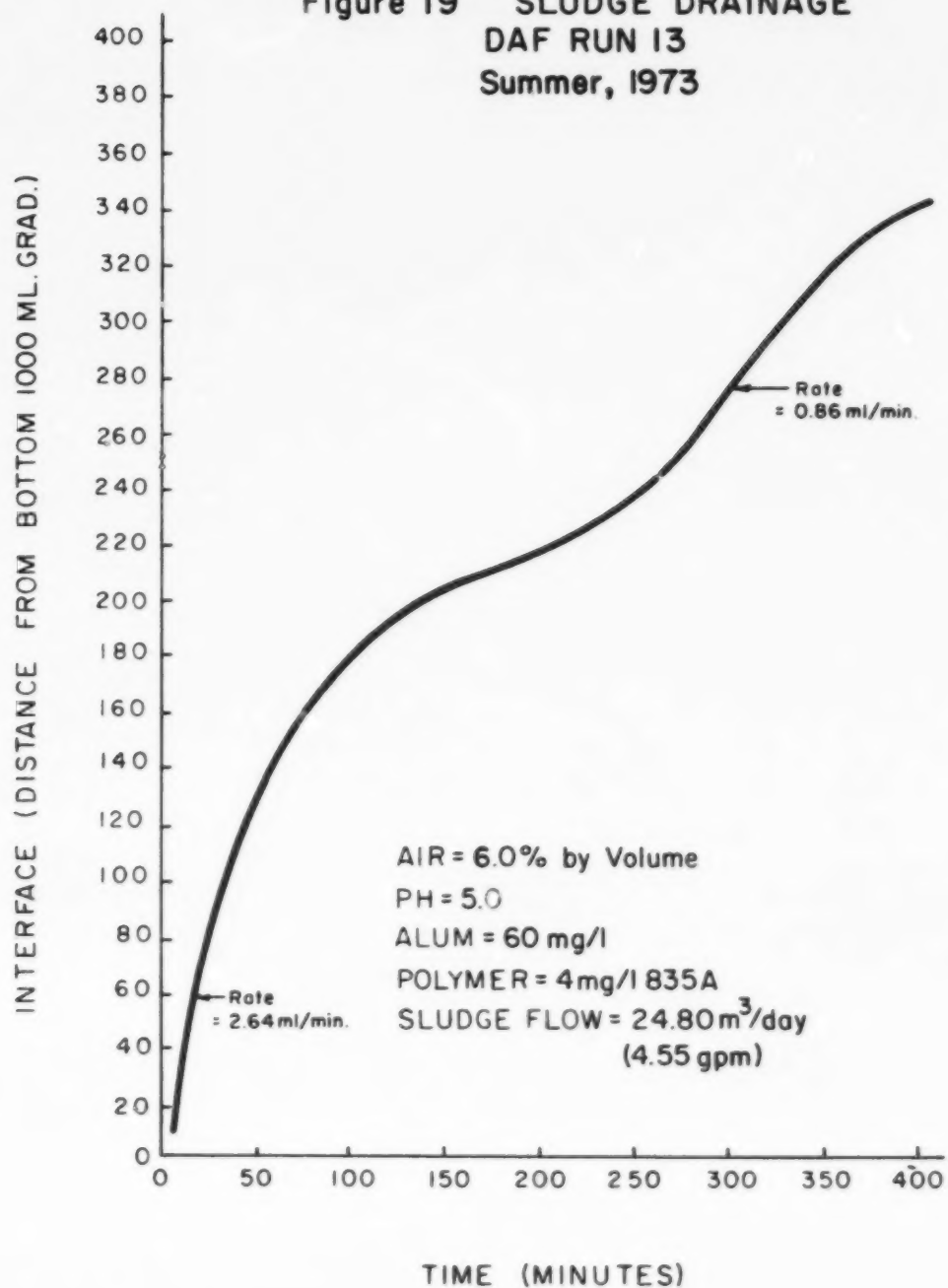


Figure 20 SLUDGE DRAINAGE
DAF RUN 14
Summer, 1973

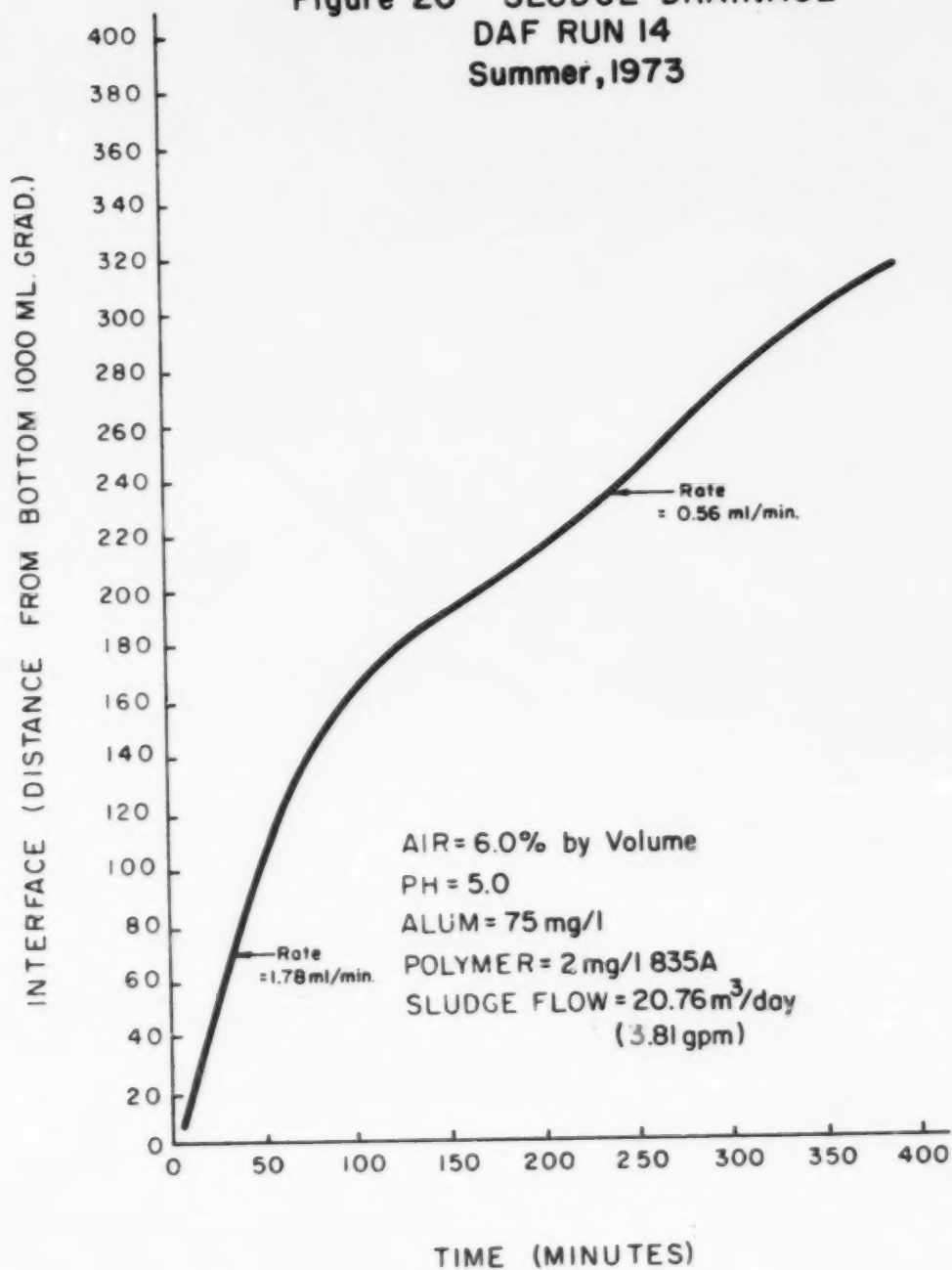
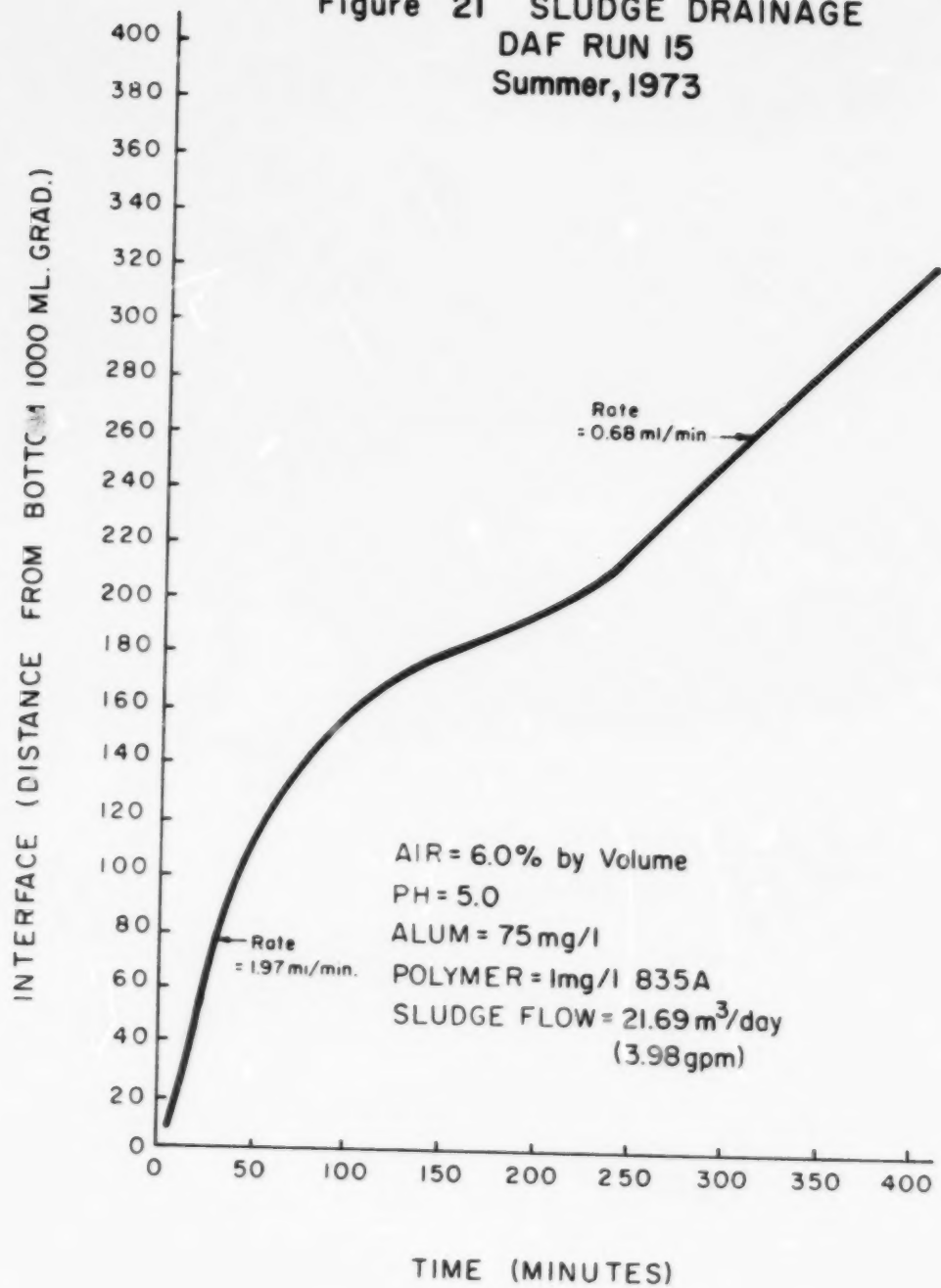


Figure 21 SLUDGE DRAINAGE
DAF RUN 15
Summer, 1973



rate for the smaller alum dose and a slightly faster rate in the second straight section of the curve. A disturbing factor, however, for the lower alum dosages (Figures 18 and 19) is the long lag period between the straight sections of the curve. The lag period is much shorter for the runs with a higher alum dosage (Figures 16 and 17). As a consequence the absolute drainage in ml is greater after 4 or 5 hours for the runs with a higher alum dosage. In summary it appears that alum feed concentration does have an effect on sludge characteristics, but a simple relationship between alum concentration and sludge drainage does not appear to exist.

The effect of polymer feed dosage on sludge drainability was also investigated. Figures 19, 20 and 21 show drainage tests where conditions are similar, except polymer feed dosage varies from 1 mg/l to 4 mg/l. The three curves show very similar shapes, drainage rates and absolute drainage at 5 hours. It appeared that polymer dosage had very little effect on drainage rate.

Injected air was another operating variable that could affect gravity sludge drainage. However, because of the limited number of pilot runs, little information about this variable was developed. Figures 14 and 15 show results of runs in the Fall of 1972. All of these runs were made with air injected at 1.5% by volume. The other sludge drainage curves were from runs in the Summer of 1973 where all runs were made with air injected at 6.0% by volume. Direct comparisons cannot be made, however, because of differences in water temperature and sludge removal rates. The average water temperature for the Fall of 1972 runs was 18° C and for the Summer of 1973 runs was 26° C. Also, during the Fall, 1972 runs two scraper blades were used where for the Summer, 1973 runs only one scraper blade was used. Since sludge was removed at a slower rate during the Summer, 1973 runs, more drainage occurred in the flotation tank. Figures 14 and 15 do indicate better drainage during the Fall, 1972 runs as compared to the Summer, 1973 runs. However, because the variables were not isolated, no conclusions can be drawn.

Overall it appears that neither alum nor polymer dosages affect sludge drainage rates to an observable degree.

BUCHNER FUNNEL

For DAF pilot plant runs 10, 13, 14 and 16 during the Summer of 1973, a Buchner funnel test of the sludge skimmings was attempted. The procedure in Appendix A was followed.

Basically, an attempt was made to find a filter cloth and a filter aide that would

optimize filtrate quality and filtration rate. However, the few attempts that were tried ended in failure. The filter cloth had a tendency to blind very quickly initially. However, if the sludge was allowed to stand in the funnel for several minutes prior to filtration a considerably larger volume of filtrate could be obtained. This was due to gravity drainage in the funnel. The captured solids in the sludge seemed to be very sticky and, therefore, very difficult to filter.

The sludge used for the filtration test was fresh sludge which was considerably aerated. No filtration attempts were made with a deaerated sludge.

Because of the limited test runs the Buchner funnel test results are probably only an indication of what could possibly be achieved by vacuum filtration. However, because of the nature of the DAF sludge, vacuum filtration does not appear promising as a sludge concentration operation.

SECTION VIII

PILOT SCALE STUDIES

GENERAL

Screening and centrifugation of DAF sludge was pilot scale tested at Plant A during the summer, 1973 canning season. Preliminary pilot screening and DAF treatment testing was performed during the fall, 1972 canning season.

The original intent of the pilot plant work was to demonstrate the treatability of shrimp canning wastewaters by the DAF process and to develop specific criteria for prototype design. The scope of the project also included the same evaluation as above for primary treatment such as screening and for sludge concentration. Several things conspired, however, to prevent completion of all objectives that were proposed.

The most limiting variable not foreseen during the project conception was very short plant runs due to a limited raw shrimp supply at Plant A. The problems Plant A experienced during this period were generally felt by most of the Gulf canners. First, the shrimp catch was below average because of adverse weather conditions. This caused tremendous competition for the available supply, and severe inflation of raw shrimp prices occurred. This, coupled with price freezes in 1973 for the finished product but not for the raw supplies, caused economic uncertainty. The result was very poor canning seasons at Plant A during the study. As discussed in Section III, because of the perishable nature of shrimp, by necessity the shrimp plants must possess a very fast process capability. This meant an extremely short plant run when the raw supply was meager.

Another important limiting variable was the pilot plant operational inflexibility. The pilot plant that was chosen had one mode of operation and could not easily be changed.

The most frustrating variable has probably been experienced by all pilot plant investigators. This was inexperience with the equipment being tested. By the time

the investigator has learned to cope with the equipment idiosyncracies and frequent malfunctions, the studytime is over. For this study the investigators certainly had their quota of these problems. This will also be discussed later in the section.

Because of these problems, only preliminary design criteria have been developed. We feel the pilot plant studies have been positive, however. The treatability of shrimp canning wastewaters by the DAF process has been demonstrated. Also, a sludge concentration method has been demonstrated. Finally, from the pilot screening studies a fairly specific design can be recommended.

PILOT SCREENING STUDIES

A total of six different screens were pilot tested during the Fall, 1972 and Summer, 1973 seasons. The screens were tested individually and in series arrangements. A tangential and a rotary screen are pictured in Figures 22 and 23.

The purpose of the screening test was to evaluate the efficiency and ease of operation of several different types of screens. Several of the larger canners had obtained experience in screening the shells and heads from their peeler wastewater with vibrating screens. These screens operated satisfactorily performing this function, but were quite expensive to operate and maintain. None of the canners, however, had experience in screening the total wastewater from a plant, which it was hypothesized would be harder to screen than the peeler wastewater. The total wastewater would contain shrimp veins, meat fragments and small shell fragments which would tend to blind a screen much quicker than the larger shells and heads. It was felt that ease of operation and economical maintenance should be a prime consideration in evaluating the pilot screens.

The screening test objectives were to be the following:

1. Evaluate the most effective screen for performing a specific solids removal function.
2. Evaluate the operating conditions of the screens such as mesh size and/or rotational speed for the rotating screens.
3. Evaluate series arrangements and compare pollutant removal efficiencies with other forms of treatment.

Most of the screening studies were performed during the summer, 1973 season. A

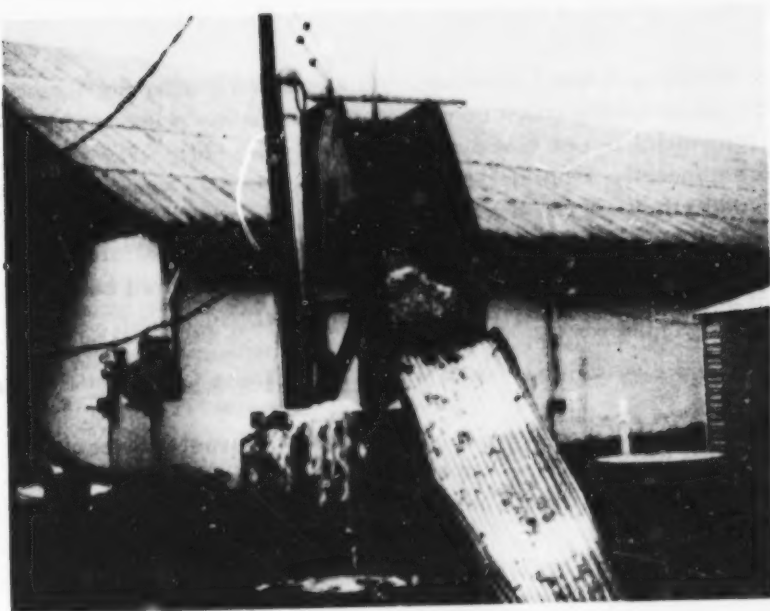


Figure 22. PILOT TANGENTIAL SCREEN

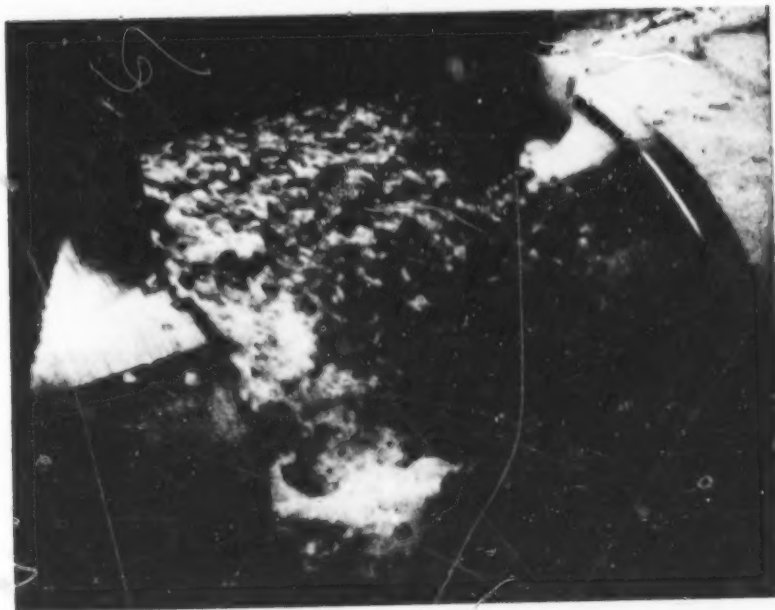


Figure 23. PILOT ROTARY SCREEN
SCREENING PEELER WATER

plant scale vibrating screen, however, was evaluated during the Summer, 1972 season, and a series arrangement consisting of a vibrating primary screen and a secondary tangential screen was evaluated during the Fall, 1972 season. The screens were generally evaluated by collecting composite samples of raw influent and screen underflows during the screening run. Some of the screening runs were, however, tested by collecting grab samples. This was necessitated because of several pilot tests operating simultaneously which was required because of an anticipated short canning season and short day runs.

A description and evaluation of each of the test screens follows:

Vibrating Screen. This screen was a 1.22 m. (48") diameter Sweco Vibro-Energy Separator with an 0.84 mm opening screen fabric. This screen was circular, mounted on coil springs, and wastewater entered from the top. The underflow passed through the screen and the screened solids were vibrated with a spiral rolling motion to the sides of the screen where they were discharged through two ports 180 degrees apart. The vibrations were caused by an electric motor whose shaft was eccentrically loaded. This screen was a permanent installation at Plant A. Wastewater from eight peeling machines and four separators was discharged by centrifugal pumps to the screen. With eight peeling machines operating (the usual practice) the flow to the screen was approximately 2725 m³/day (500 gpm). The average results for this screen are shown in Table 25.

This screen removed suspended solids very effectively; the removal efficiency approached 40%. The screen, however, was not nearly as efficient in removing settleable solids; the removal was less than 60%, leaving a mean settleable solids residual of approximately 20 ml/l in the underflow. BOD-5 and total solids removal appeared to average at around 15% removal. The screened solids were fairly dry with an average value of 16.2% solids.

At Plant A the screen surface was periodically sprayed throughout the day with a high pressure hose to prevent blinding. The waste did tend to partially blind the screen, but not totally. The amount of spraying required for optimum operation is not known. Since this unit was not a pilot unit but a necessary plant scale operation, no changes were made in the screen during the study period. Controllable variables, such as degree of eccentricity of the shaft motor size, stiffness of the spring mounts, cleaning devices and screen mesh were not evaluated.

Centrifugal Screen. This screen was a 0.305 m. (12 in.) diameter Sweco centrifugal Wastewater Concentrator. With this unit, wastewater was pumped to the middle

of a spinning cylindrical screen. The liquid was spun through the screen and was removed as effluent. The solids too large to pass through the screen dropped out and were removed as concentrated solids. The manufacturer claims that the screen rotational velocity in combination with the impingement velocity of the influent results in a vector velocity that allows the screen to remove particles smaller in size than the wire openings.

The pilot screening unit tested was operated and set up by Sweco personnel. Sampling and wastewater analysis was done by study personnel. The unit was tested on total composite discharge wastewater during plant processing. The peeler and separator wastewater part of this discharge had been pre-screened with a 0.84 mm opening vibrating screen. Therefore, most of the large peeling solids had been removed, but this wastewater did contain additional solids from deveining, blanching, inspection and canning operations which were not pre-screened.

The operating variables available were: interchangeable 0.035 mm opening and 0.097 mm opening screens and flow rate. Seven test runs were made in which operating conditions were varied on each. Average results are shown in Table 26.

Settleable solids removal with this screen was excellent with the mean value being 89% removal. BOD-5 and suspended solids removals were 8.6% and 17.2% respectively. For the seven runs the concentrate flow averaged 14.4% of the influent flow to the screen with a maximum of 36.4% and a minimum of 5.4%. The higher concentrate flows generally occurred with the use of the 0.035 mm opening screen. Removals of suspended solids were generally better using the 0.035 mm screen; however, removal of BOD-5 was observed to be better using the 0.097 mm screen.

Rotating Screen. This screen was a Hydrocyclonics Rotostrainer. The screen had a diameter of 0.64 m. (25 in.) and a length of 0.61 m. (24 in.). The unit had a screen opening of 0.5 mm. The cylindrical screen had the appearance of well screen with a wedge wire grid. The unit was equipped with a weir influent box for even influent distribution to the screen. The water passed through the screen openings on the top of the screen, fell through the center of the cylinder and passed through the screen openings again on the bottom, thus backwashing any solids trapped in the screen. The solids were carried on the top surface of the screen to a scraper bar where the solids were removed.

The operational variables available for testing this unit were: rotational speed of the screen and influent flow rate. The unit was tested with raw peeler wastewater with shells. The unit was tested for three runs. The only

Table 25. VIBRATING SCREEN ^a EVALUATION
POLLUTANT REMOVAL EFFICIENCIES

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
BOD-5	16.1	35.9	1.8
Total Solids	15.1	39.0	11.8
Suspended Solids	39.9	81.3	23.8
Settleable Solids	57.1	75.7	41.9

^a Sweco 0.84mm opening

Table 26. CENTRIFUGAL SCREEN ^a EVALUATION
POLLUTANT REMOVAL EFFICIENCIES

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
BOD-5	8.6	16.7	0.0
Suspended Solids	17.2	37.6	3.4
Settleable Solids	89.0	93.3	84.7

^a Sweco Wastewater Concentrator

operational variable tested was the rotational speed of the screen. Considerable pump clogging problems were experienced in pumping the tested wastewater to the screen influent, therefore, the flow rate variable was not evaluated. The average results from evaluating the screen are shown in Table 27.

Table 27. ROTATING SCREEN^a EVALUATION
POLLUTANT REMOVAL EFFICIENCIES

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
Suspended Solids	26.7	48.5	6.1
Settleable Solids	47.8	60.6	36.3

^a Hydroclonics Rotostrainer

The removal of suspended and settleable solids was somewhat less for this screen than for the vibrating screen even though the screen opening for the rotating screen (0.5 mm) was less than for the vibrating screen (0.84 mm). The screened solids, however, were fairly dry. One sample was tested at 22% dry solids.

Tangential Screens. Tangential screens from three different manufacturers were evaluated. They were: the Bauer Hydrasieve, the Hydrocyclonics Hydroscreen and the Dorr-Oliver 45° DSM screen. The Hydroscreen and the DSM screens were tested with raw peeler water only and the Hydrasieve was tested with raw peeler water and total composite process wastewater (peeler water pre-screened).

The Bauer Hydrasieve test unit was 0.457 m wide and 0.85 m high. The test unit was supplied with screens with four different openings: 0.50 mm, 0.75 mm, 1.0 mm and 1.5 mm.

The Hydrasieve had a headbox and an influent weir for even influent distribution and had a mechanism to feed the wastewater on the screen tangentially. The screen bars were wedgewire and were transverse across the screen. The wedgewire bars curved downward between the vertical supports to cause the flow to divide into separate streams between the vertical supports. The

manufacturer claims this helps prevent clogging and blinding.

This unit was used for pretreatment of wastewaters for the DAF pilot plant. The wastewater screened at this location was total composite process wastewater. Therefore, the tangential screen was operating as a secondary screen in series with the vibrating screen for peeler wastewaters and operating as a primary screen for the remainder of wastewaters produced in the plant (deveining, fluming, blanching, canning and raw receiving). The average results are shown in Table 28.

Table 28. TANGENTIAL SCREEN ^a EVALUATION
POLLUTANT REMOVAL EFFICIENCIES ^b

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
COD	4.4	36.0	0
Total Solids	4.7	40.0	0
Suspended Solids	0	47.0	0
Settleable Solids	55.6	80.0	39.0

a Bauer Hydrasieve (1.0 mm Screen opening) at 272 m³/day (50 gpm)
b From Total Composite Process Wastewater

The results indicate very poor removal efficiencies of COD, total solids and suspended solids but fairly good removal of settleable solids. The complete results for settleable solids indicate a residual average underflow concentration of 8.8 ml/l. The average results above are all from runs using a 1.0 mm screen opening. Trials were made with a 0.5 mm opening screen but severe blinding resulted.

Blinding was somewhat of a problem screening this type of wastewater. The peeler wastewater had been pre-screened and, therefore, the only solids left in the influent water were small shell fragments, shrimp veins and small meat fragments. The small shell fragments tended to build up in layers between

the transverse screen wedgewires. This type of clogging usually started at the top of the screen and caused a water jump or uneven water distribution which resulted in a considerable amount of water in the screenings. A periodic hosing of the screen (every 30 minutes) solved this problem. The screen also tended to completely blind over with a slimy material. This was impossible to remove with a hose and a wire brushing was required about once an hour.

The Hydrasieve was also tested as a primary screen on raw peeler wastewater. All the screen openings available were tested at $272 \text{ m}^3/\text{day}$ (50 gpm). The evaluation was limited, however, because only one short run was made with each screen opening. The results are shown in Table 29. These results indicate that the 0.50 mm opening screen produced the best results. This screen, however, tended to blind fairly quickly with a slime build-up. This unit with a 0.75 mm opening screen performed excellently during the short test run. Residual settleable solids in the underflow was only 14 ml/l. The other screen openings (1.0 mm and 1.5 mm) also performed without blinding problems, but solids removal was inferior to the 0.75 mm opening screen. The screened solids were extremely wet when first leaving the screen but tended to gravity drain very quickly. The screenings were 8% dry weight solids at the point of leaving the screen. This was due probably to a noticeable amount of water continuously trickling from the end of the screen. The test unit was probably several years old and the seals between the sides of the wedge wire screen and frame were worn causing water to channel down the inside walls. This was probably the major cause of wet screening solids.

The Hydrocyclonics Hydroscreen was also tested with raw peeler wastewater. This screen was similar in design to the Hydrasieve but with several differences, which include: the screening surface was actually three separate screens, all at slightly different angles to the vertical; the influent weir did not direct the water tangentially to the screen but was actually a small jump; and the screening surface of the Hydroscreen test unit was about one foot longer than the Hydrasieve. The Hydroscreen unit was also apparently new and in excellent condition.

The differences in the screen design were apparently significant. Table 29 shows the solids removal results for the Hydroscreen. As can be seen, the residual settleable solids in the underflow was 22 ml/l. This was considerably higher than the Hydrasieve. However, screened solids from the Hydroscreen were approximately 18% dry solids when leaving the screen. This was due to the solids staying on the screen much longer, and, also, no noticeable amount of water was observed trickling from the end of the screen. Only one test run

Table 29. PILOT SCREEN EVALUATIONS
272 m³/day Influent Flow

Manufacturer	Screen (mm)	Conditions	Test	Screen Influent	Screen Effluent	% Removed
Hydrasieve by "Bauer"	0.50	--	Set. solids ^b	70	12	82.9
			Susp. solids ^c	1250	1290	0
	0.75	--	Set. solids	42	14	66.7
			Susp. solids	1240	358	69.5
	1.00	--	Set. solids	50	15	70.0
			Susp. solids	1910	910	52.4
	1.50	--	Set. solids	70	33	52.9
			Susp. solids	1065	645	39.4
Hydroscreen by "Hydrocyclonics"	0.50	--	Set. Solids	70	22	68.6
			Susp. solids	2250	855	62.0
DSM by "Dorr-Oliver"	0.50	--	Set. solids	33	Screen Failed by blinding	
			Susp. solids	660		
	0.71	--	Set. solids	33	13	66.7
			Susp. solids	660	650	1.5
	1.00	--	Set. solids	33	18	45.5
			Susp. solids	660	680	0
Rotostrainer by "Hydrocyclonics"	0.50	10 RPM	Set. solids	33	21	36.3
			Susp. solids	660	490	25.6
		5 RPM	Set. solids	33	18	45.4
			Susp. solids	660	340	48.5
		2 RPM	Set. solids	33	13	60.6
			Susp. solids	660	620	6.1

^a Water tested = raw peeler water with shells

^b ml/l

^c mg/l

was made with this screen and a 0.5 mm screen opening was used at 272 m³/day. No blinding problems were observed during the test run.

The Dorr-Oliver 45° DSM screen was also tested with raw peeler wastewater. This screen is also similar in design to the Hydrasieve. Important differences are: the DSM screen has a continuously curved surface; the DSM test unit was approximately twice as high as the Hydrasieve; and the DSM test screen was only approximately 0.305 m (12 inches) wide where the Hydrasieve was 0.457 m wide. The manufacturer describes the operation of DSM screen as:

The DSM screening device employs a concave wedge bar type of screen. In operation, the feed to the screen is introduced tangentially at the proper velocity and flows across the concave screen surface at right angles to the openings between the wedge bars. Each of the wedge bars acts as a knife on the underside of the passing slurry. A layer of liquid and undersize solid particles strikes the sharp leading edge of the bar and is sliced off and directed downward through the slot into the screen box. The layer peeled off by this unique slicing action produces undersize particle separations smaller than the size of the wedge bar openings, thus preventing blinding of the screen. The oversize material continues to flow across the screen being continually dewatered as it moves along and is discharged at the far end of the screen. The volume of undersize that passes through the openings between the wedge bars is largely determined by how well the slurry is held in contact with the screen surface. The continuously curved surface design and the velocity across the surface provide this holding action by the centrifugal force created.

In the investigators opinion, this screen has a superior design and it is regrettable that a thorough evaluation could not be performed. Test runs with screen openings of 0.5 mm, 0.71 mm, and 1.0 mm were made. Results are shown in Table 29. The velocity across the face of the screen was very fast, and, as a consequence, a slight blinding of the 0.5 mm screen caused a complete failure because of water discharged at the end of the screen. With the 0.71 mm opening screen, residual settleable solids of only 13 ml/l in the underflow was tested. The 1.00 mm opening had a residual settleable solids of 18 ml/l. No indication of blinding was observed with these two screens. The screened material had approximately 18% dry solids content when leaving the screen.

The advantages and disadvantages of the tested screens will be discussed in Section IX.

PILOT DISSOLVED AIR FLOTATION STUDIES

A pilot DAF treatment unit was evaluated for two canning seasons using the total composite discharge from Plant A. The first test season, the Fall of 1972 canning season, was intended to be of a preliminary nature where equipment bugs could be worked out and chemicals could be evaluated.

For the second season, the Summer of 1973 canning season, objectives were to intensely evaluate the operational variables of the DAF process while treating shrimp canning wastewaters. Because of a multitude of problems these objectives were not completely accomplished, but a considerable amount of operational data was collected.

The first major decision facing the project was to select the type of DAF system to pilot test. Preliminary jar tests were performed in the early Summer, 1972, canning season. An extremely good coagulant system was found that produced a very tough floc. With this knowledge and knowing that the Gulf shrimp canning industry required an economical treatment system both in capital and operating costs, and, because of land shortages a very compact system, the decision was made to pilot test the total pressurization system.

The Pacific DAF system manufactured by the Pollution Control Division of Carborundum Company was selected. This pilot system offered the features: a screening and surge tank module, a chemical addition module and automatic pH control with the flotation cell module. The DAF pilot plant was set up and made operational in the early Fall of 1972. The testing program during this season was titled the Preliminary Pilot Plant Phase. The pilot DAF unit is pictured in Figures 24 through 27.

The objectives for this project phase were:

1. Set up and de-bug the operation of the mechanical pilot plant.
2. Optimize chemical dosages.

This was believed to be a realistic program that could be accomplished during a two month canning season.

Figure 28 shows a schematic of the pilot plant set-up and sampling stations. The sludge concentration operation and sampling were not part of this project phase. The pilot plant was nominally rated at 272 m³/day (50 gpm) and this flow was used for this project phase. Influent flow was pumped from a wet well that contained the total plant composite flow to the top of a tangential screen. The screen underflow drained to a surge tank beneath the screen where the coagulant and acid

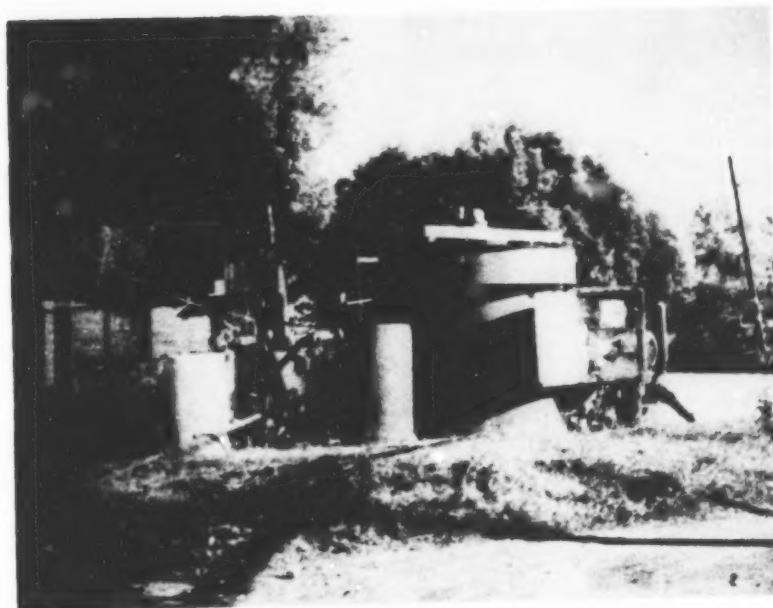


Figure 24. PILOT DAF UNIT



Figure 25. PILOT DAF UNIT

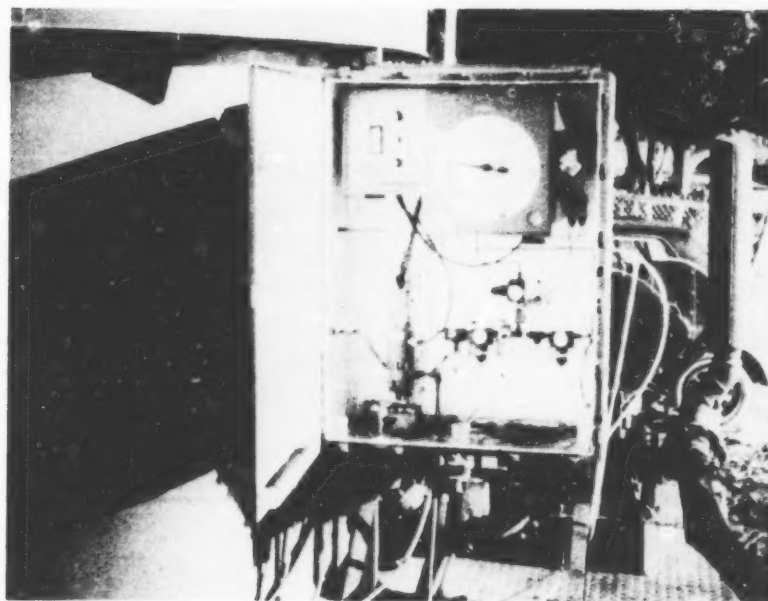


Figure 26. PILOT DAF UNIT
Pressurization Pump, Tank and Air Injector

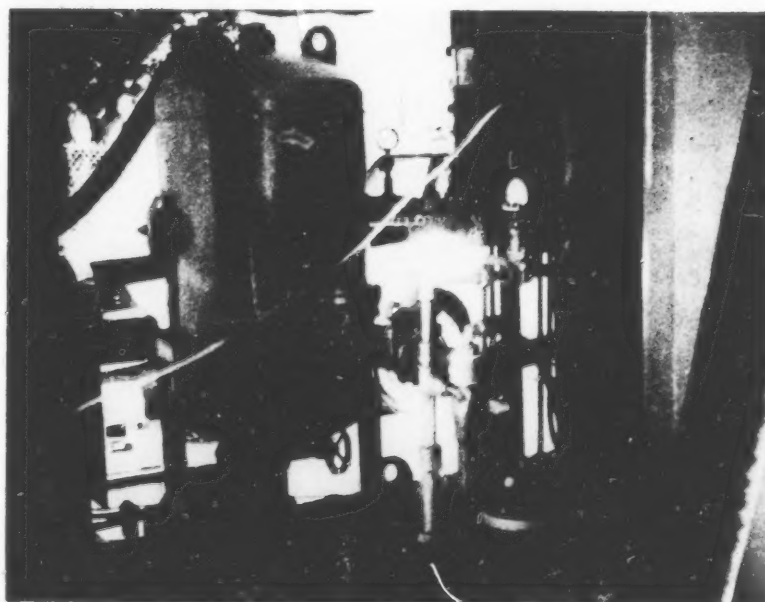
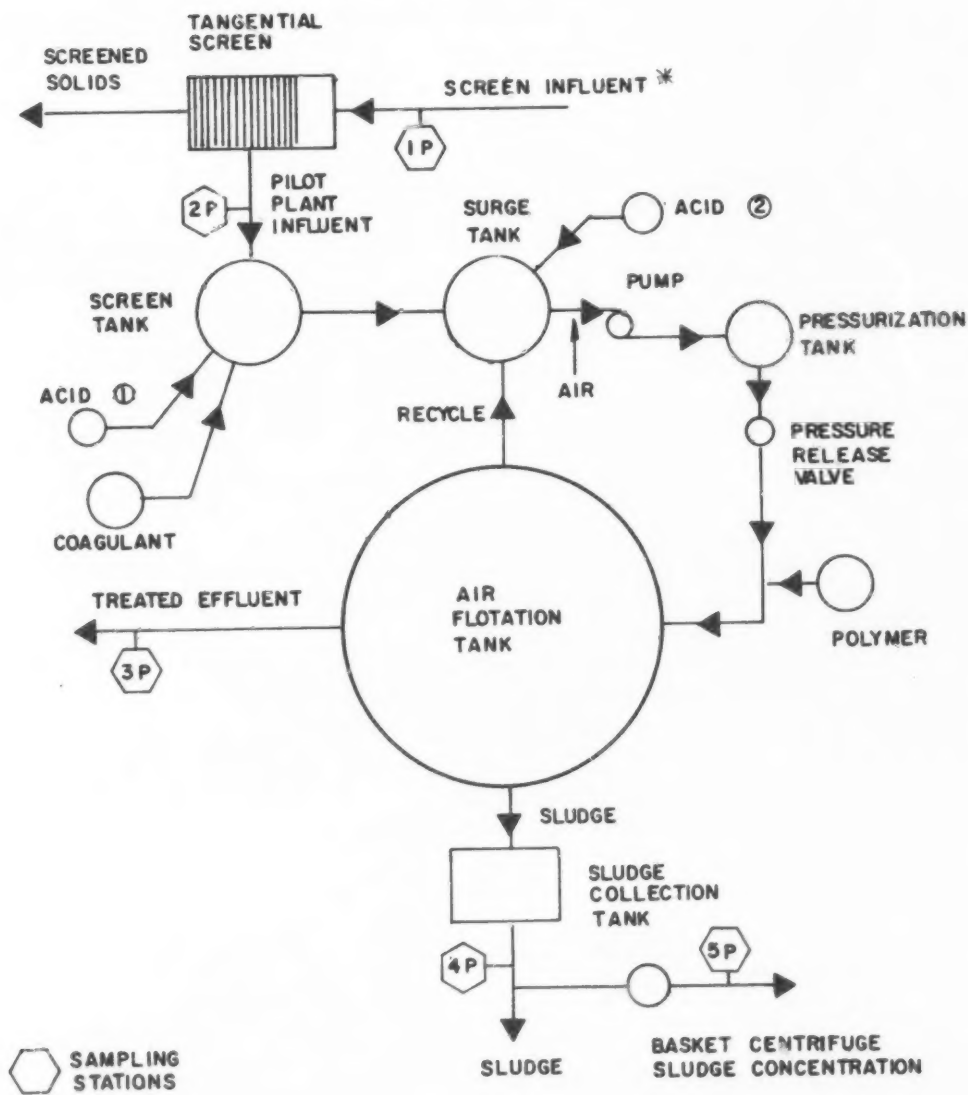


Figure 27. PILOT DAF UNIT
Automatic pH Controller

Figure 28 DISSOLVED AIR FLOTATION
PILOT PLANT SCHEMATIC
AND SAMPLING STATIONS



* RAW CANNERY WASTEWATER
AFTER SCREENING THROUGH
20 MESH VIBRATING SCREEN

were added with a chemical addition pump. The contents were then mixed with a mechanical mixer and pumped to another surge tank which served as the wet well for the pressurizing pump. A recycle from the flotation cell effluent was also discharged to this tank. The recycle flow was controlled with a float valve that was controlled by the water level in the surge tank. The recycle was strictly a method of providing a continuous flow for the pump. With a wastewater influent of $272 \text{ m}^3/\text{day}$ (50 gpm) the recycle would also provide $272 \text{ m}^3/\text{day}$ (50 gpm) for a constant pressurized flow of $544 \text{ m}^3/\text{day}$ (100 gpm) at 40 psig (2.81 kgf/cm^2) pressurization. Air was injected into the pump suction through a rotometer immediately downstream from the surge tank. The wastewater was then pumped to a non-packed, 1 minute detention time, pressurization tank. The wastewater then passed through a pressure release valve and then to the bottom of a coagulation tube which was a small cylindrical tank at the center of the air flotation cell. The flow was upward in this tank because of air bubble buoyancy. The wastewater discharged from the top of the coagulation tube radially into the main body of the flotation cell. Solids were scraped from the top of the flotation cell into a sludge hopper and effluent supernatant traveled from near the bottom of the tank through three standpipes to a top effluent weir where a portion was recycled and a portion discharged as effluent.

A total of 12 runs were made with the DAF treatment system during this phase of the study. The constant operating conditions for all runs were:

1. Flow Influent - $272 \text{ m}^3/\text{day}$ (50 gpm).
2. Injected Air - $0.17 \text{ m}^3/\text{hr.}$ (6 cu. ft./hr.)
3. Pressurization - 2.81 kgf/cm^2 (40 psig).
4. Acid Addition - Screen tank.
5. Alum Addition - Screen Tank.
6. Polymer Addition - Flotation Cell Influent.

The variable conditions for each of the runs were:

1. Alum coagulant dosage.
2. Polymer dosage.
3. pH.

Pilot plant dimensions of interest were:

1. Diameter of Flotation Cell - 2.29 m. (7.5 ft.).
2. Volume of Flotation Cell - 8.24 m^3 . (290 ft.³)
3. Side Water Depth - 2.01 m. (6.6 ft.).
4. Surface Area of Flotation Cell - 4.11 m^2 (44.2 ft.²)

5. Volume of Pressurization Tank - 0.38 m^3 (100 gal.).
6. Volume of Coagulation Tube - 0.38 m^3 (100 gal.).

Computed design variables of interest were:

1. Flotation Cell detention time - 22 minutes.
2. Overflow rate - 132.3 m/day (2.26 gpm/ft.^2).
3. Pressurization Tank detention time - 1 minute.
4. Flocculation Tank detention time - 1 minute.
5. Assumed fraction of saturation in pressurization tank - 0.5.
6. Average Air/Solids Ratio = 0.0440.
7. Average Cell Solids Loading = 1.30 Kg/hr./m^2 ($0.267 \text{ lbs/hr.ft.}^2$)

Mechanical problems hampered all of the runs in the preliminary pilot plant phase. The automatic pH control equipment malfunctioned from the start and manual pH adjustment was required. This was accomplished by using a constant discharge acid feed pump, periodically checking pH values with a portable meter and making continuous adjustments of the feed pump discharge. This method did not work well and pH control was poor.

Alum coagulant dosages ranged from 150 mg/l down to 75 mg/l and polymer dosages from 5 mg/l to 0 mg/l. Control of pH at 5.0 was attempted, but actual values fluctuated from 3.0 to 6.7. Table 30 shows the testing conditions for this testing phase.

Table 30. PILOT PLANT OPERATING CONDITIONS
Dissolved Air Flotation Unit
Preliminary Pilot Plant Series
Fall 1972

Run	Date	Coagulant ^a mg/l	Polymer ^b mg/l	pH
1	11/13/72	150	0	6.5
2	11/14/72	150	0	3.0
3	11/17/72	150	5	3.0
4	11/20/72	150	2	6.7
5	11/20/72	150	5	6.7
6	11/21/72	150	5	5.2
7	12/01/72	150	5	4.9
8	12/05/72	150	2	4.7
9	12/05/72	150	5	4.8
10	12/05/72	100	5	5.0
11	12/05/72	100	2	5.0
12	12/05/72	75	5	5.0

a - aluminum sulfate

b - magnifloc 835 A

Best treatment was observed at alum and polymer dosages of 75 and 5 mg/l, respectively, and with pH controlled at 5.0. The control of pH was observed to be extremely important for good treatment. When the pH was at the optimum value of 5.0 the floated sludge had the appearance of chocolate malted milk, but when the pH wandered from the optimum as much as ± 0.5 the new sludge would be white and far less dense. The visual quality of the effluent would also almost immediately worsen.

With the DAF plant operating correctly, the effluent was almost crystal clear, but with a small amount of white haze and a small amount of floc carryover. When the pH or one of the coagulants was not at optimum, the white haze intensified and, if corrections were not made, turned to a turbid pinkish color which was the same color as the influent. Table 31 shows the results of this testing phase.

Table 31. PILOT PLANT EFFICIENCY
Dissolved Air Flotation
Preliminary Pilot Plant Series
Fall, 1972

Run	COD		% Removal	Total Suspended Solids		% Removal
	Influent mg/l	Effluent mg/l		Influent mg/l	Effluent mg/l	
1	--	2400	--	--	--	
2	--	2200	--	--	--	
3	--	1370	--	--	--	
4	3450	1800	48	825	350	
5	2350	1500	36	490	355	
6 ^a	1900	1400	26	118	158	
7	3250	1100	60	354	82	
8	3050	900	71	220	60	
9	3050	950	69	220	74	
10	3050	1300	57	220	64	
11	3050	1350	56	220	68	
12	3050	900	71	220	32	

^a Plant processing frozen shrimp

The study was hampered by lack of processing at Plant A and short plant runs when the plant did process fresh shrimp. Raw shrimp supplies were very scarce and the plant resorted to processing peeled frozen shrimp. Run number 6 was made with the wastewater from this product. The DAF pilot plant was able to treat this wastewater

to about the same residual values as for raw shrimp. One problem encountered was foaming during pumping.

The conclusions of the preliminary DAF pilot plant phase were:

1. The system was extremely sensitive to pH and this variable would have to be controlled very precisely.
2. Alum dosages as low as 75 mg/l provided good treatment.
3. Polymer dosages in the range of 2 to 6 mg/l would be required for efficient treatment.

During the spring of 1973, repairs were made to the pH control system and to other minor mechanical problems. The Pilot Plant Phase was started in May, 1973. The objectives of this phase were to:

1. Continue the chemical optimization.
2. Optimize solids loading rate.
3. Optimize air/solids ratio.

A total of 18 runs were made with the DAF treatment system during this phase of the study. Sixteen (16) of these runs were made at constant flow and overflow rate while evaluating chemical dosage (Pilot Series I) and two (2) runs were made with constant chemical dosages while evaluating overflow rate. (Pilot Series II).

For Pilot Series I the following operating conditions were used for all runs:

1. Flow - $272 \text{ m}^3/\text{day}$ (50 gpm).
2. Injected Air - $0.68 \text{ m}^3/\text{hr}$.
3. Pressurization - 2.81 kgf/cm^2 (40 psig).
4. Acid Addition - Surge Tank.
5. Alum Addition - Screen Tank.
6. Polymer Addition - Flotation Cell Influent.

The variable conditions for Pilot Series I, were the same as for the preliminary pilot plant series. In Pilot Series I computed design variables were the same as for the preliminary pilot plant series, except for the following:

1. Average air/solids ratio = 0.1339.
2. Average Cell Solids Loading = 1.61 Kg/hr/m^2 ($0.33 \text{ lbs/hr/ft.}^2$).

All of the DAF pilot plant runs in Pilot Series I had generally a very short duration. Most of the runs were between one and two hours, which was the same as the plant processing times. Between 40 and 50 minutes from start-up was required for the

formation of a good thick sludge layer and the simultaneous development of an effluent that appeared well treated. This time corresponded to two detention times or two passes through the flotation cell. Therefore, complete equilibrium conditions were probably established during the two hour runs, but not for a one hour run.

Alum coagulant dosages ranged from 150 mg/l to 50 mg/l and polymer dosages from 10 to 0.5 mg/l. Best pollutant removals were obtained at alum and polymer dosages of 75 mg/l and 2 mg/l respectively. A pH of 5.0 ± 0.2 was maintained for most runs. A pH of 9.0 was maintained for one run and extremely poor treatment resulted. For three runs, pH values from 6.1 to 6.5 were maintained and poor treatment resulted. Table 32 shows the test conditions for this pilot plant phase.

Table 32. PILOT PLANT OPERATING CONDITIONS
Dissolved Air Flotation Unit
Pilot Series I
Summer 1973

Run	Date	Alum (mg/l)	Polymer (a) (mg/l)	pH	pH Control Chemical
1	5/29/73	75	10	5.0	H ₂ SO ₄
2	5/30/73	75	5	5.0	H ₂ SO ₄
3	5/31/73	150	10	5.0	H ₂ SO ₄
4	6/01/73	150	5	5.0	H ₂ SO ₄
5	6/04/73	100	4	5.0	H ₂ SO ₄
6	6/04/73	150	4	6.5	None
7	6/04/73	150	4	9.0	Na OH
8	6/05/73	300	4	6.2	None
9	6/06/73	600	4	6.1	None
10	6/07/73	75	4	5.0	H ₂ SO ₄
11	6/07/73	0	4	5.0	H ₂ SO ₄
12	6/11/73	50	4	5.0	H ₂ SO ₄
13	6/12/73	60	4	5.0	H ₂ SO ₄
14	6/13/73	75	2	5.0	H ₂ SO ₄
15	6/13/73	75	1	5.0	H ₂ SO ₄
16	6/14/73	75	0.5	5.0	H ₂ SO ₄

(a) Magnifloc 835 A

The effluent with good runs was almost crystal clear with a turbidity of less than 20 units. A small amount of floc carryover persisted and caused this small amount of turbidity. The effluent was visually crystal clear between floc particles. The effluent BOD-5 for good runs was below 400 mg/l, the effluent COD was below

1200 mg/l, the effluent suspended solids was below 100 mg/l and the effluent protein was below 600 mg/l. Table 33 shows the COD and suspended solids removal efficiencies for each run. Table 34 shows the mean removal efficiencies for all parameters.

Table 33. PILOT PLAN EFFICIENCY
Dissolved Air Flotation
Pilot Series I
Summer 1973

Run	COD		% Removal	Total Suspended Solids		% Removal
	Influent mg/l ^a	Effluent mg/l ^b		Influent mg/l ^a	Effluent mg/l ^b	
1	3400	1500	55.9	510	350	31.4
2	3400	1300	61.0	590	110	81.4
3	3400	1600	52.9	620	210	65.6
4	4000	1400	65.0	427	152	64.4
5	3600	1500	58.3	333	68	80.0
6	3100	1750	43.5	344	320	7.0
7 ^c	--	--	--	--	--	--
8	4000	2000	50.0	1135	232	79.6
9 ^c	--	--	--	--	--	--
10	3500	1250	64.3	664	97	85.4
11 ^c	--	--	--	600	600	0.0
12	3200	1500	53.1	585	438	25.1
13	4100	1250	69.5	613	87	85.8
14	3300	1200	63.6	355	49	86.2
15	3600	1250	65.3	560	122	78.2
16	3200	1150	64.1	625	110	82.4

a - Sample Station 2 P

b - Sample Station 3 P

c - Very low treatment efficiency

Table 34. DAF PILOT PLANT EVALUATION
Pilot Plant Phase, Summer, 1973
Pilot Series I - Chemical Optimization
Pollutant Removal Efficiencies

Parameter	Mean Removal %	Maximum Removal %	Minimum Removal %
BOD-5	65.1	80.0	50.0
COD	59.0	69.5	43.5
Total Solids	14.9	42.9	0.0
Suspended Solids	65.6	85.6	7.0
Protein	52.5	91.1	25.7
Turbidity	83.0	97.5	61.9
Ortho Phosphate as P	27.5	38.2	15.4
Total Organic Carbon	61.4	62.8	60.0

Control of pH was again observed to be very critical. When pH varied as much as ± 0.5 from the optimum of 5.0, the sludge and effluent quality decreased significantly. Lag time for the pH control system was a problem for the first two runs. When the influent pH wandered slightly, the system would over-compensate and push the pH outside the acceptable range. It would take the automatic system 20 or 30 minutes to bring the pH back to a steady pH 5.0. The location of the concentrated feed was then changed from the screen tank (See Figure 28) to the surge tank. The pH control sensor was located immediately downstream from the surge tank and less lag time and better pH control resulted.

The jar tests and the preliminary DAF pilot tests had shown that the alum-acid coagulant was very slowacting, and for this reason the acid was added to the screen tank. When the pH lag problem resulted, the alum and acid feeds were changed to the surge tank and better pH control resulted. However, poor floc formation became a problem, so the alum feed was changed back to the screen tank. Then floc formation and treatment efficiencies immediately increased.

Pilot Series II was concerned with optimizing the solids loading rate. From Pilot Series I the chemical dosages were optimized at alum, polymer and pH values of 75 mg/l, 2 mg/l and 5.0 respectively. All runs in Pilot Series II used these optimum dosages. Table 35 shows treatment efficiencies for this testing. The intention was to make several runs with these dosages at different influent flow rates; however, this pilot series was abbreviated because of a premature ending of the shrimp season at the test plant. Three runs, however, were completed with influent flow rates of 136 m³/day (25 gpm), 272 m³/day (50 gpm) and 408 m³/day (75 gpm). The influent suspended solids concentration for each run was slightly different. Therefore, flow and solids loading were not directly proportional. The results are shown in Figure 29.

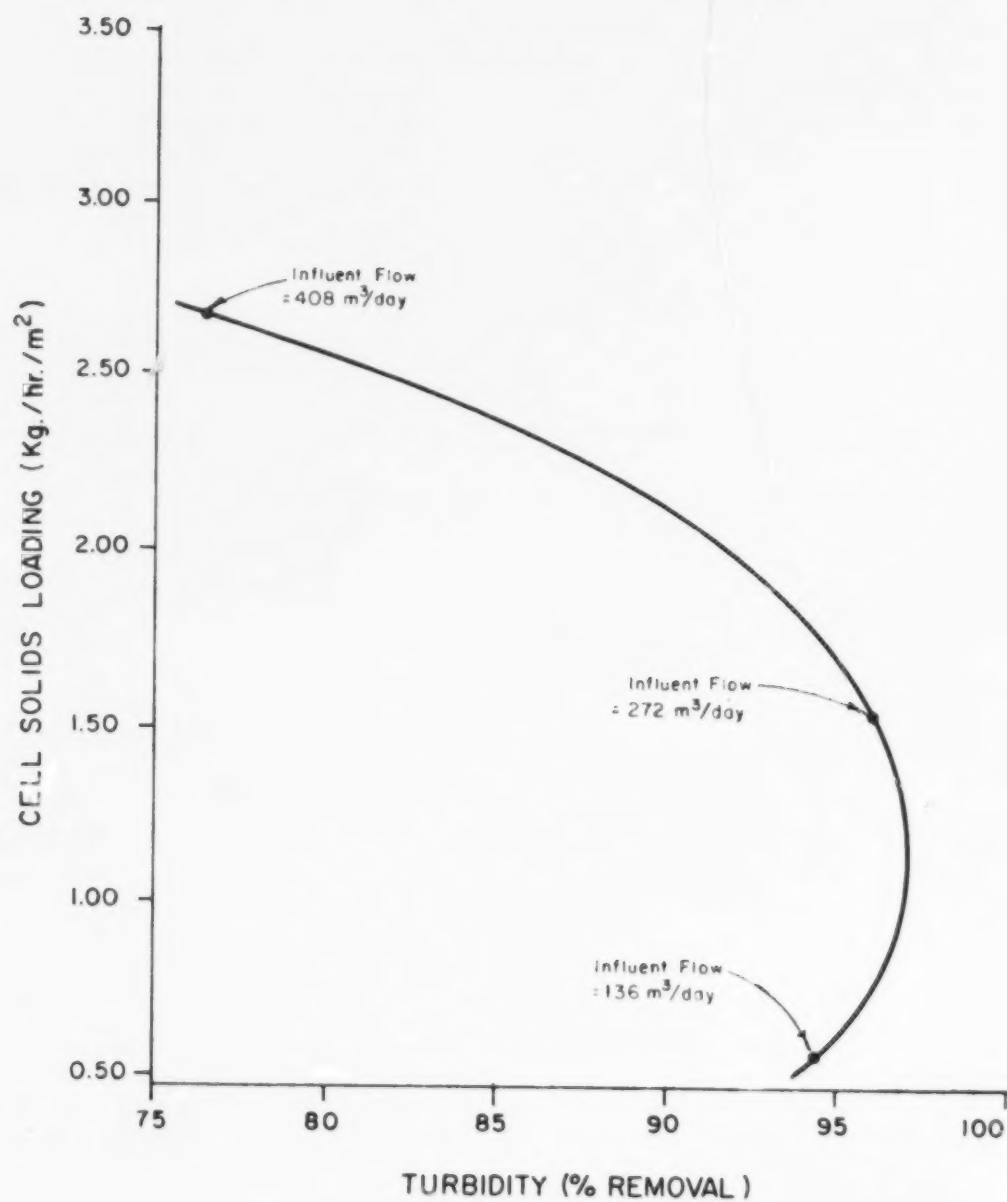
Table 35. PILOT PLANT EFFICIENCY
Dissolved Air Flotation Unit
Pilot Series II
Summer 1973

Run & Date	Test	Influent ^a mg/l	Effluent ^b mg/l	% Removal
1 6/22/73	pH	7.5	5.0	
	COD	3600	1800	50.0
	Turbidity	450	105	76.7
	Phosphate as P	90	75	16.7
	Total Solids	4150	4000	3.6
	Tot. Susp. Solids	490	170	65.3
	Oil & Grease	944	144	84.7
2 6/25/73	pH	7.9	5.1	
	COD	3200	1550	51.6
	Turbidity	370	20	94.6
	Phosphate as P	80	70	12.5
	Total Solids	3686	3578	2.9
	Tot. Susp. Solids	390	110	71.8
	Oil & Grease	760	110	86.8

a - Sample Station 2 P

b - Sample Station 3 P

Figure 29 PILOT DAF PLANT EVALUATION
SOLIDS LOADING VS. TURBIDITY REMOVAL



From Figure 29 it appears that optimum cell solids loading is approximately 1.22 Kg/hr/m² (0.25 lbs/hr/ft.²) with a corresponding influent flow of approximately 218 m³/day (40 gpm).

Pilot Series III was intended to be optimization of air/solids ratio; however, this series was not run because of lack of processing at Plant A. Several values of air/solids ratios were computed from similar runs during the Preliminary Pilot Plant Series, Pilot Series I and Pilot Series II. The results of these computations are shown in Figure 30. where A/S ratios are plotted against removal of suspended solids.

From Figure 30 it appears optimum A/S ratios are within the range of 0.10 and 0.15. This is from 3 to 4 times literature values for other industrial wastes. With this very high optimum A/S ratio a total pressurization DAF system would be superior to a recycle pressurization system.

The concentration and flow rate of the flotation sludge was measured for most of the pilot runs. Mean results are shown in Table 36.

Table 36. DAF PILOT PLANT EVALUATION
Flotation Sludge Characteristics

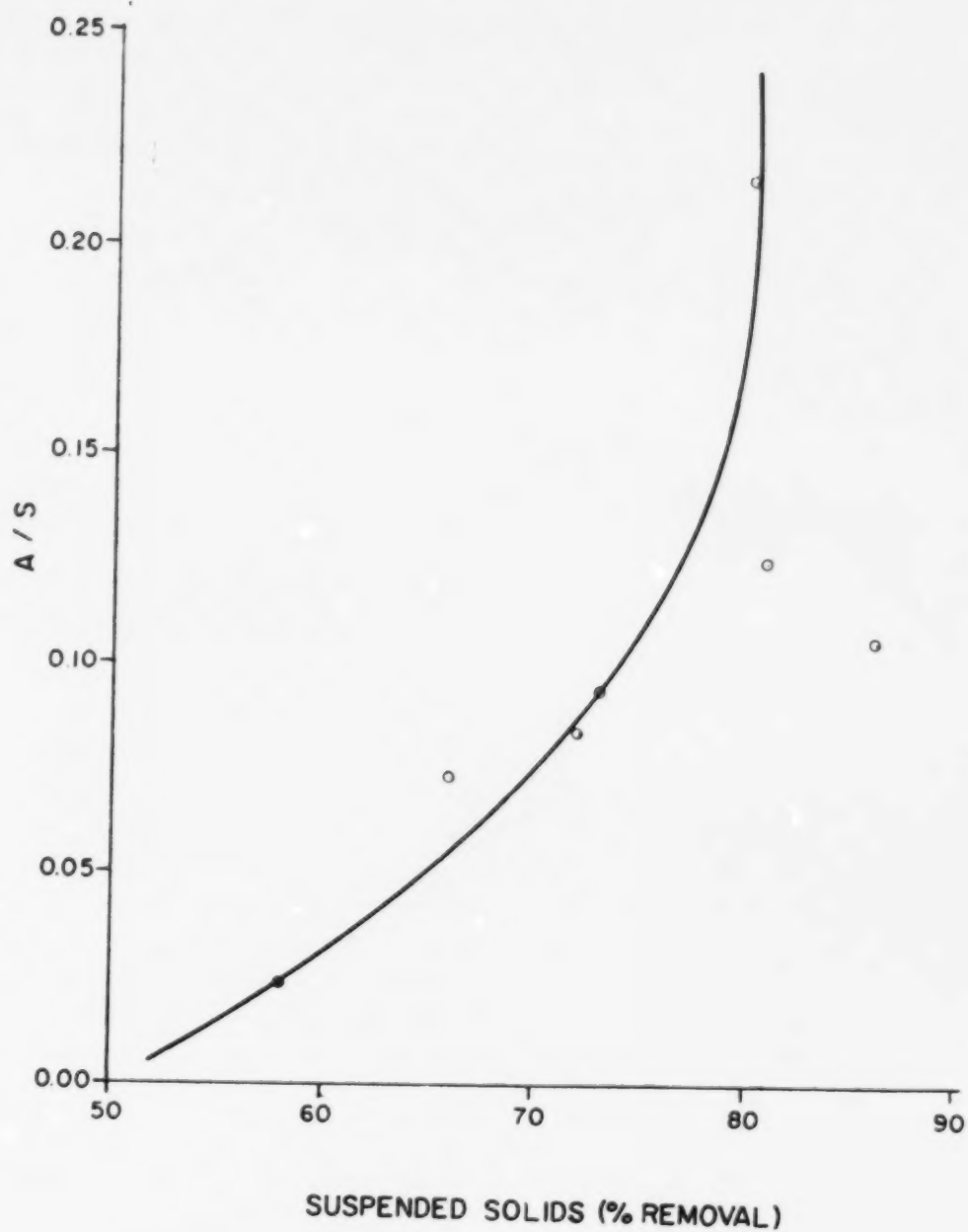
Parameter	Units	Mean	Maximum	Minimum
Dry Solids ^a	%	5.0	6.7	2.6
Flow ^b	m ³ /day	23.3	32.5	6.4
Protein	mg/l	15,819	26,318	6,963

Attempts were made to find relationships between chemical feed concentration and sludge characteristics; however, with the relatively small number of runs tested, none could be found. It seems certain, however, that sludge volume will increase with increased chemical dosages.

The conclusions of the DAF pilot plant phase are:

1. The optimum chemical dosages were alum - 75 mg./l, polymer - 2.0 mg./l and pH - 5.0.

Figure 30 PILOT DAF PLANT EVALUATION
A/S RATIO VS. SUSPENDED SOLIDS REMOVAL



2. The alum floc was slow in forming and should be fed into the system as early as possible.
3. Concentrated acid for pH control should be fed into the system immediately upstream from the pH control sensors in order to reduce response time.
4. Polymer should be fed into the system immediately upstream of the flotation cell.
5. The retention time of the DAF cell should be designed on an optimum solids loading of 1.22 Kg/hr./m^2 (0.25 lbs/hr/ft^2).
6. The injected air to the DAF cell should be designed on an optimum A/S ratio of 0.125.
7. The influent flow was concentrated by volume to an average of 5.1 % floated sludge and 94.9 % treated effluent.
8. The floated sludge had an average dry solids content of approximately 5.0%.

PILOT SLUDGE CENTRIFUGATION STUDIES

The flotation sludge skimmed from the top of the DAF pilot plant was concentrated in a basket type pilot centrifuge manufactured by DeLaval Separator Company. The centrifuge had the following characteristics:

Method of Feed	: Batch
Feed Volume	: 9.5 liters (2.5 gallons)
Basket Type	: Solid
Material Removal Method	: Skimmer

The centrifuge was operated at 1200 G's for all the test runs. The flotation sludge was fed to the centrifuge while spinning at approximately 3.78 liters/min. (1.0 gpm) from a bucket for a total feed volume of 9.5 liters (2.5 gallons). The feed sludge was fresh, having been collected from the DAF unit immediately prior to testing. After feeding, the sludge was spun from 2 to 10 minutes, after which the material was removed with a skimmer. The liquid phase was removed first and the volume was measured. The solid phase or centrifuge cake qualitatively was soft and very skimmable. The entire cake was removed from the basket except for a very thin

layer next to the basket. The volume was measured and the per cent dry solids was analyzed.

A total of nine test runs were made with the basket centrifuge. Spin time was varies from two to ten minutes. On two of the runs, polymer conditioners were tested. Average results are shown in Table 37.

Table 37. PILOT CENTRIFUGE EVALUATION
Mean Results

Parameter	Mean % Dry Solids	Mean Volume (Liters)
Feed Sludge	3.36	9.5
Centrifuge Cake	6.23	2.2
Centrate	1.05	3.7
Air	0.0	3.6

Using the mean results above the average solids capture was 77.8%. The volume reduction considering the cake and the feed sludge was approximately 77%. The appearance of the cake was solid but soft and could probably be pumped with a positive displacement pump. The separate additions of 10 mg/l of non-ionic and cationic polymers appeared to be of no value in increasing the percentage of dry solids or reducing the cake volume.

The conclusions of the pilot centrifuge studies are:

1. The evaluation was only preliminary because of the limited number of runs.
2. The concentration of the cake and solids capture was encouraging for a preliminary test.

SECTION IX

DISCUSSION

GENERAL

This section will discuss, basically, the data and results presented in other sections. Comparisons of different manufacturer's equipment will be made. The advantages and disadvantages, in our opinion, of how the equipment treats or responds to shrimp canning wastes will be discussed. The problems encountered during the study and how they could influence the results and conclusions are discussed. Finally, areas where further study or research could be of benefit are discussed.

WASTEWATER CHARACTERISTICS

From the start of the study the hypothesis was made that wastewater characteristics from all Gulf shrimp canning plants would be similar because of similar processing methods. Section VI compares the total discharged wastewaters from six different plants. In order to make direct comparisons, weights of discharged pollutants were computed in terms of weights of processed shrimp.

The data indicate that the original hypothesis was inaccurate. Total COD discharged varied by a three times (3x) factor among the plants tested. Total solids varied by a factor of almost four times (4x). This information indicates that the study plant (Plant A) or any of the Gulf plants does not have a "typical" total discharged wastewater. Because the total wastewater is composed of wastes from so many plant operations and has so many variables, it is not surprising that a "typical" discharge does not exist.

Comparing the wastewaters from one unit operation, the peeling operation, gives a great deal of insight into conditions that cause the variability. The peeling operation is performed with the same type of equipment and supplied by the same manufacturer. The equipment operating variables are feed rate of shrimp per hour per peeler and the quantity of water used per unit of time. Other variables would be the size, age and species of the shrimp being processed. Supposedly, the size, species and age of the shrimp govern the feed rate and the water required for

optimum peeling. Theoretically, when processing the same type of shrimp, peeler wastewaters should be very similar at different plants.

The results presented in Section VI indicates that peeler wastewaters were very similar at four out of five tested plants for COD and total solids discharged. The fifth plant's peeler wastewater was not typical; however, it was known that the shrimp being processed on the test day were relatively old and, therefore, not typical.

The processing variables that exist beyond the peeling operation are as follows:

1. Method of conveying shrimp varies and can be pumping, wet fluming or dry conveying.
2. The percentage of processed shrimp that is deveined.
3. The method of blanching, whether batch or continuous.
4. Characteristics of the raw water supply.
5. Washdown period and methods.

These variables could be significant in establishing characteristics of the total discharged wastewater, since there were extreme differences measured at the test plants, although the measured peeler wastewaters were uniformly typical. Because the study data gives little insight about the relative importance of the plant process variables on wastewater characteristics, each plant should be tested individually to determine the characteristics of its total wastewater discharge.

TREATMENT BY SCREENING

A study objective was to examine the problem of screening all the process wastewater from a shrimp canning plant. This presented a problem significantly different from screening just peeling wastewater, which has been the industry practice up to this time. The peeling wastewaters were screened fairly efficiently by vibrating screens at Plants A, B and D and by a tangential screen at Plant C. The residual settleable solids in the screened wastewater generally averaged about 15 ml/l for these installations. The large amount of settleable solids in the peeling wastewater probably assisted the continued operation of the screens by scouring the smaller solids that caused blinding and clogging. The total wastewater, however, would contain shrimp veins and small fragments of shrimp meat and shells not present in the peeling wastewater.

Considerable data were collected on screening the peeler wastewater alone by several types of screens. Also, considerable data were collected at Plant A on screening the total wastewater discharge with the peeler water being prescreened by a 20 mesh (0.84 mm opening) vibrating screen. However, because of plant piping limitations no data were collected on primary screening of the total process wastewater.

On screening peeler wastewaters the following screens were evaluated:

- A. Tangential Screens
 - 1. Bauer "Hydrasieve".
 - 2. Hydrocyclonics "Hydroscreen".
 - 3. Dorr-Oliver "DSM".
- B. Rotating Screen - Hydrocyclonics "Rotostrainer".
- C. Vibrating Screen - Sweco "Vibro-Energy Separator".

Of the three types of screens the tangential screens produced the best effluent with the lowest residual settleable solids concentration in the effluent. These screens also produced the wettest screening of the three types tested. The rotating screen produced the driest screenings and the vibrating screen performed midway to the other two types for both criteria.

The tangential screens consumed no power, therefore, were best for this category. The vibrating screen was the worst and the rotating screen, which required only a fractional horsepower motor, was midway. The rotating screen was only slightly behind the tangential screens in this respect because it was much lower than the tangential screens and the pumping head required would be lower.

In ease of operation, the rotating screen was best. During a short evaluation it showed no tendency to blind or clog. The vibrating screen required a frequent water hosing and was midway in this category. The tangential screens required frequent hosing and periodic brushing with a steel brush.

In anticipated operating cost, the rotating screen appears to be the best because no operator would probably be required and maintenance should be minimal. The tangential screen should be midway in this category even though no maintenance costs are likely and an operator will probably be needed. The vibrating screen, because of its mechanical nature, is last because of expected high maintenance costs and the need for an operator.

On screening the total process wastewater with the peeling wastewaters pre-

screened, the following screens were evaluated:

1. Tangential Screen - Bauer "Hydrasieve".
2. Centrifugal Screen - Sweco "Wastewater Concentrator".

The centrifugal screen produced the best effluent with a residual settleable solids concentration of about 1.0 ml/l. This screen, however, removed only an average of 8.6% of BOD-5 and 17.2% suspended solids, so the residual concentrations in the screened effluent were still very high. The disadvantage of this screen was the very voluminous concentrate flow. This flow would need to be treated separately. Treatability of the concentrate flow was not evaluated.

The tangential screen removed settleable solids to a residual of about 10 ml/l, removed an average of 4.5% of BOD-5 and, on an average, removed no suspended solids. The screenings tended to be very wet because of a continual blinding problem which resulted in water discharged off the end of the screen. The screen tended to blind because of a slime layer which could only be removed with a wire brush.

In summary, of the three screen types evaluated while screening peeler wastewaters, the rotating screen and the tangential screens seemed to be superior over the vibrating screen. In screening the total process wastewater the centrifugal screen performed well, but the large concentrate flow volume was a disadvantage.

In recommending a screen for total process wastewater discharge, the tangential screen has to be the choice. Its advantages of simple operation, low maintenance and adequate screening efficiency far outweigh its disadvantages.

TREATMENT BY DAF

A study objective was to pilot plant the dissolved air flotation (DAF) process and to develop design criteria for future full scale design. The first decision point was to select the DAF type, whether full flow pressurization, partial flow pressurization or recycle pressurization. Literature information on protein wastewaters indicated that either full flow pressurization or recycle pressurization should be chosen.

The full flow pressurization system offered the very large advantage of lower capital costs. The major disadvantage to this system, technically, was that any flocculation prior to pressurization would be sheared in the pressurization pump. All flocculation would then have to occur in a short period within the flotation cell and could result in immature floc and poor separation. If this occurred, then this type of system would not be suitable for treating shrimp canning wastewaters.

The recycle pressurization system had the reported disadvantage of high capital costs. Its advantage was that a floc could be preformed in a separate flocculation tank and be fed to the air flotation cell by gravity, thus preserving the fully matured floc. This would facilitate good separation of the floc and the remaining water.

Preliminary jar testing was performed at Plant A during the summer of 1972. A coagulant system consisting of pH adjustment, alum and an anionic polymer was found to give an extremely tough, stable floc. The decision was then made to pilot test a total pressurization system for the first season and, if results were unacceptable, then change to a recycle pressurization system.

A total pressurization DAF pilot system manufactured by the Carborundum Company was tested during the fall, 1972 canning season. Mechanical problems throughout this season prevented a thorough testing. However, runs where proper controls could be maintained resulted in very efficient treatment with an effluent that was close to sparkling clear. A small amount of floc carryover to the effluent did occur even with the best runs, but there seemed to be no relationship between a small amount of floc carryover and effluent COD. The polymer dosage seemed to have the greatest effect on floc carryover because when no polymer was used, a great amount of floc carryover occurred which resulted in much higher effluent COD.

Because of the potential that this unit demonstrated, it was decided to pilot test this unit for a second season if the manufacturer would completely recondition the unit. The corrective repair work was performed during the winter and spring of 1973.

The pilot DAF unit performed very well mechanically during the summer, 1973 canning season. However, Plant A experienced an extremely poor processing season, and therefore only about one-half the number of runs required for a thorough evaluation were made. Most of the runs were also of very short duration, lasting only for one or two hours. It was doubtful that complete equalization occurred with the shorter runs.

Since the chemical addition system was not completely optimized during the previous testing season this testing series was rerun. The pH control system and the chemical addition pumps performed well during this season. Effluent quality was observed to be very sensitive to pH. The optimum pH was in the range of 5.0 to 5.2. If the pH was adjusted to as high as 5.5 or as low as 4.5 the physical appearance of the floated sludge started to change immediately. The color of the sludge during optimum processing was a rich chocolate brown, and in non-optimum conditions it immediately started to turn white. The white sludge had a very low density of about one percent dry solids, and obviously very little solids separation was occurring.

Floc carryover was still a problem with the DAF unit during this period. There was again no observable relationship between effluent COD and minor degrees of floc carryover. A major floc carryover problem was observed when runs were made with polymer dosages of less than 2.0 mg/l. This was in contradiction to the jar tests where good separations were made with lower polymer dosages. This probably demonstrates the economic trade off necessary when using a full pressurization system; capital costs will be lower but operating costs will probably be somewhat higher.

Several preliminary runs or parts of runs were made using no chemicals or pH adjustment, but using air flotation only. The effluent was not tested because there was no observable treatment. The effluent appeared to be of exactly the same quality as the influent, and the floated sludge was extremely light and bubbly. Very few captured solids were observed in this type of sludge. Flotation bomb bench scale tests were made with no chemical but with full air. Virtually no reduction in TOC resulted. Runs were made with the DAF pilot plant with inefficient coagulant systems and virtually no removals of COD, turbidity or suspended solids occurred. These facts made it very clear that an efficient coagulant system must be used if significant pollutant reductions are to be achieved.

Another observed problem with the DAF unit was the relatively long start up time required. The pilot unit was started each morning using fresh water. The chemical injection pumps and process pumps were started and adjusted prior to the start up of the shrimp processing plant. This was done in order to get the maximum run time possible and to check the start up time required. After the wastewater entered the flotation cell approximately 40 minutes was required before a relatively clear effluent was observed. This time was approximately 2.0 retention periods of the flotation cell. Therefore, it is obvious that if a shrimp cannery processes for only one or two hours and 40 minutes are required for treatment plant start-up, a very poor daily average treatment will result.

The operation and maintenance of a DAF treatment unit should be relatively simple for most shrimp canners. The plant system is composed of standard items such as pumps, valves and mixers which all shrimp canners should be able to maintain with few problems. The DAF unit should operate automatically and should only require periodic spot checks by an operator.

IN PLANT CHANGES

The treatment operations pilot tested during the study had the ultimate capabilities of removing only insoluble or suspended solids. This is also true of nearly all

other types of available treatment operations. The exceptions are primarily biological treatment and reverse osmosis operations which have the ability to remove solubles. Therefore, the ultimate efficiency of practical treatment methods for the shrimp canning industry will depend on the respective percentages of insoluble and soluble waste pollutants. Because of this, in-plant changes would be desirable in order to decrease the percentage of soluble waste pollutants in the discharged wastewater.

A common method of transporting the raw product from one process operation to the next is by water fluming. This method of transport will increase the concentration of soluble solids and will also increase the BOD-5 thereby reducing the ultimate efficiency of the treatment. The take-up of soluble pollutants by the transport water will be proportional to the time of transport and the agitation in the flume. Therefore, it is assumed that if the flumes were eliminated and replaced by dry conveyers a significant amount of soluble pollutants would not enter the wastewaters.

During the bench testing phase it was found that the age of the wastewater had a profound effect on the treatability. COD removals of 70% and greater were possible with fresh wastewater but only about one-half this efficiency was possible with wastewaters as old as 12 hours. Therefore, biochemical changes are occurring, possibly ammoniaification of the protein, that change the soluble/insoluble pollutant ratios.

This same phenomena can occur when non-fresh shrimp is processed by the cannery. This is probably a major reason why the characterization data showed so much scatter. Therefore, the shrimp canneries can probably expect low wastewater treatment efficiencies when non-fresh raw shrimp are processed.

The Literature Review, Section IV, compares soluble/insoluble pollutant ratios of Alaskan shrimp peeler wastewater using Model A (raw peelers) and Model PCA (pre-steam) peelers. The PCA peeler wastewater showed a significantly higher percentage of insoluble solids. This should make the PCA peeler wastewater much more treatable.

The Gulf shrimp canners at the present use Model A peelers. The canners should initiate research into equipment modifications or commission original new designs that will reduce the wastewater pollutant concentration or increase the insoluble pollutant percentage in order to make the wastewater more treatable.

SOLID WASTE DISPOSAL

In this discussion flotation sludge will be considered a solid waste. Two methods of dewatering were investigated during this study: centrifugation and gravity drainage. The economics of shell dewatering and drying of dewatered sludge and shells will be discussed based on laboratory investigations of moisture contents and unit weights. The scope of the project did not include pilot plant investigations for dewatering shells and drying shells and sludge.

Sludge dewatering by centrifugation was investigated on a preliminary basis. The results of this testing are not verified because only one run with each test condition was made. Chemical conditioning was not optimized, and no noticeable benefit was observed with the two chemical addition runs made. The tests did establish that centrifugation could, as minimum performance, decrease the sludge volume one-fourth and increase the dry solids content by two fold. Optimization of this operation could greatly increase this performance.

Sludge dewatering by gravity drainage was investigated on a bench scale for a number of pilot DAF runs. The sludge drained quite readily by gravity. Approximately 4 hours of drainage was required to equal the centrifuge performance in reducing the volume. This could be an economical method for sludge dewatering.

Problems were observed, however, which could cause severe problems with a full scale installation. The sludge separated initially into two phases with a clean interface. The drained water was on the bottom and the lighter sludge continued to float. The water was relatively clear with obvious good suspended solids capture. This continued for only about one hour and then small amounts of the sludge began to settle. It was quite obvious at this stage that even small amounts of agitation would promote large scale settling of the sludge. Because of this, design of a continuous, full scale, gravity unit would be extremely difficult. From the batch bench scale studies, a prediction can not be made as to the efficiency of a full scale continuous unit. A full scale batch unit would be difficult to operate.

At this stage the most feasible sludge dewatering operation appears to be centrifugation. From the pilot plant work, this operation can be sized with confidence for a full scale installation. The chemical optimization can be performed on-line, if need be.

TREATMENT ECONOMICS

The estimated treatment costs are presented in Appendix C, Cost Study Data. Estimated treatment costs are presented for an 8-peeler size cannery and a 4-peeler

size cannery. Approximate costs for other cannery sizes can be obtained by straight line interpolation. The estimated operation and maintenance (O & M) costs are presented in Cost/day. A day is defined as eight hours of operation. To obtain the O & M costs for two hours of plant processing, the costs would be 25 per cent of the values shown.

The capital cost estimate is based on the hypothetical treatment system shown in Figure 31. The estimate is broken down into the following elements:

1. basic treatment system,
2. auxiliary operations to basic treatment,
3. in plant changes, and
4. solid waste disposal.

The basic treatment system is an independent system in which water is treated by DAF and the solid wastes are dewatered and hauled to a land fill. The auxiliary operations are basically chemical additions that will greatly increase the treatment efficiency of the DAF operation. In-plant changes basically involve modifications of the method for transporting raw shrimp from gravity water flumes to dry conveyers, with some wastewater piping changes included. The estimates for dried solid waste disposal include screening, dewatering, drying of screenings and sludge, grinding and packaging of the solid waste.

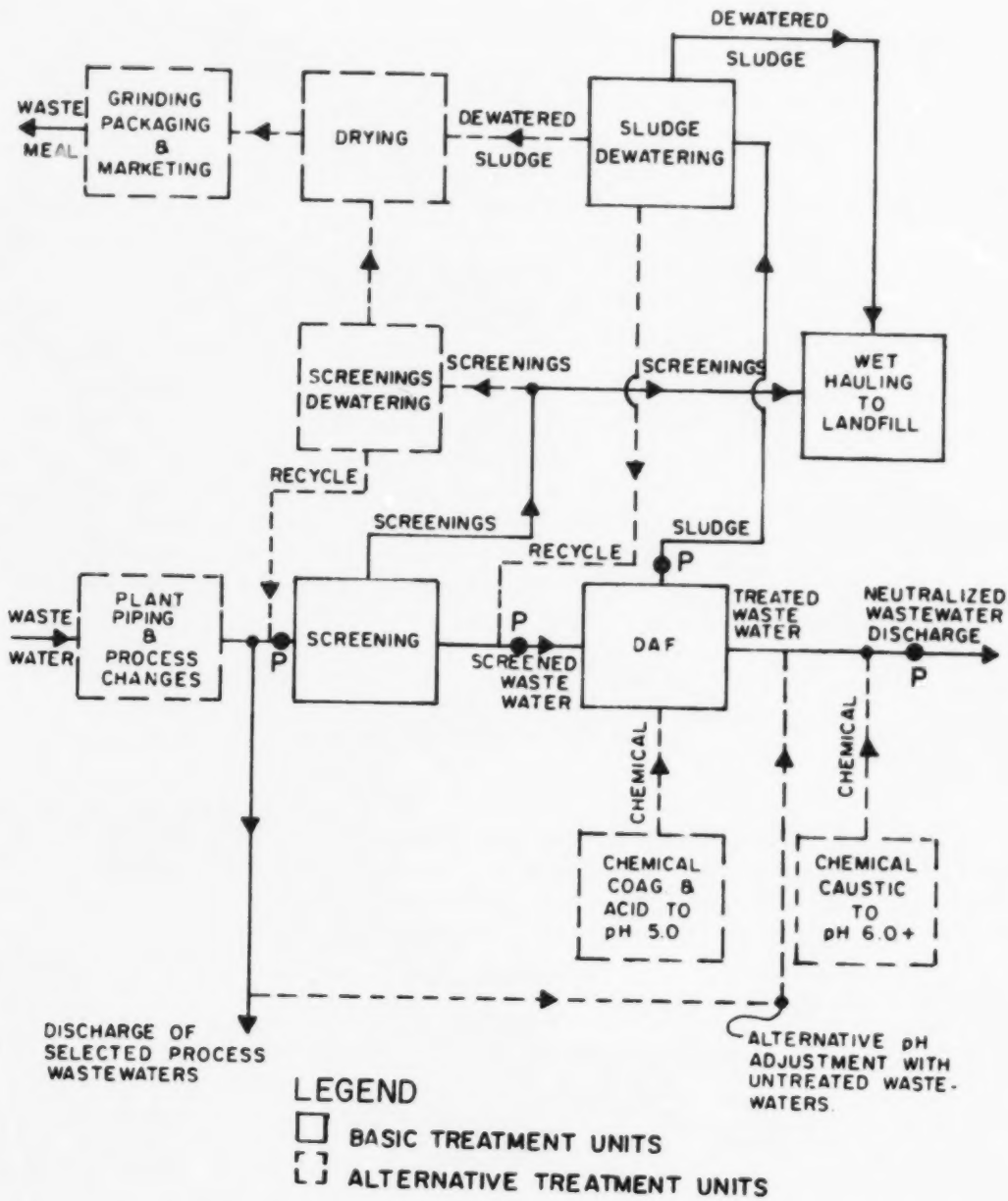
For an 8-peeler plant the estimated capital costs for a basic treatment system are \$172,800. With chemical addition operations added, the costs increase to \$208,000. When a drying system is added, the total estimated costs are \$287,450.

The O & M costs will vary directly with plant processing times. The estimated costs for basic treatment, including a treatment plant operator and solid wastes truck driver, are \$104.00 per 8 hour day. If a plant operates for a greater or lesser length of time, the costs will be approximately proportional to this value.

The O & M costs increase drastically when chemical addition is added. The maximum costs will be associated with maximum possible treatment efficiency. If a lesser degree of treatment is required for discharge, the chemical O & M costs could decrease drastically. The maximum estimated costs are \$51.37/day for an 8-peeler plant. This would give a combined basic treatment plus chemical costs of \$155.37/day.

If drying is added to the basic system, the O & M costs rise only slightly. Addi-

Figure 31 PROPOSED SHRIMP CANNING WASTEWATER TREATMENT SCHEMATIC



tional costs associated with the dryer are fuel and power costs. These are substantial, but the dryer will replace wet hauling to a land fill. The estimated costs for an 8-peeler plant with basic treatment plus chemical addition plus drying is \$158.57/day.

The total treatment costs per day of processing for a cannery will be O & M costs plus amortization of capital costs. Amortization for this analysis was based on 120 operating days per year, interest of 7% and expected equipment life of 10 years. The total costs/day for an 8-peeler and a 4-peeler plant for each treatment category follows in Table 37. Taxes are not included.

Table 38: WASTE TREATMENT ECONOMICS
TOTAL COST/DAY
(Amortized Capital Costs Plus O & M)

Treatment	8-Peeler Plant Cost/Day	4-Peeler Plant Cost/Day
Basic Treatment	208.22	154.40
Basic & Chemical	280.83	216.46
Basic, Chemical & Solids Drying	330.05	248.23

An 8-peeler plant will process, on the average, 25,000 kg (55,000 pounds) of raw shrimp during 8 hours of processing. Approximately 3,628 kg (8,000 pounds) of dried waste meal can be expected from dried shells, meat and sludge. The additional total costs/day for drying as compared to basic plus chemical is \$49.22 per day. Therefore, this analysis shows that if the waste meal is worth as little as \$0.0135/kg (\$0.0061/pound), the drying operation could be economically feasible for the 8 peeler cannery.

For a 4 peeler plant, average processing for 8 hours is 12,500 kg (27,500 pounds) of raw shrimp. Approximately 1,814 kg (4,000 pounds) of dried waste meal would be produced. The additional drying costs/day are \$31.77/day. Therefore, if dried waste meal is worth as little as \$0.0175/kg (\$0.0079 per pound), the drying operation could be economically feasible for the 4-peeler cannery.

SECTION X

BIBLIOGRAPHY

1. "Domestic Sewage and Seafood Processing, Wastewater Survey, Westwego, Louisiana, " U. S. Department of Interior, Federal Water Pollution Control Administration, Robert S. Kerr Water Research Center, April, 1968.
2. Preservation and Processing of Fish and Shellfish, Quarterly Progress Report. Technological Laboratory, Bureau of Commercial Fisheries, Fish and Wildlife Service, U.S.D.I., Ketchikan, Alaska, 1968.
3. Pollution Abatement and By-Product Recovery in Shellfish and Fisheries Processing, CRESA, EPA water Pollution Control Research Series, 12130 FJQ, June, 1971.
4. Soderquist, M.R., Canned and Preserved Fish and Seafoods Processing Industry Development Document for Effluent Limitations Guidelines and Standards of Performance, EPA. Contract No. 68-01-1526, July, 1973.
5. Peterson, P.L., Treatment of Shellfish Processing Water by Screening and Air Flotation, (unpublished), National Marine Fisheries Services, Kodiak, Alaska, 1972.
6. Dehn, W.T., and Holz, T.W., Investigation of Screening Equipment for Salmon Cannery Wastewater (unpublished) for National Cannery Association, Seattle, Washington, December, 1972.
7. Claggett, F.G., and Wong, J., Salmon Canning Wastewater Clarification, Part II. Fisheries Research Board of Canada, Vancouver Laboratory, British Columbia, February, 1969.
8. Sawyer, C.N., Chemistry for Sanitary Engineers. McGraw-Hill, 1960.
9. Morrison, R.T., and Boyd, R.N., Organic Chemistry, 2nd Edition, Allyn and Bacon, Inc., Boston, 1966.
10. Weber, W.J., Jr., Physiochemical Processes for Water Quality Control, Wiley Interscience, 1972.

11. Eckenfelder, W.W., Jr., Industrial Water Pollution Control, McGraw-Hill, 1966.
12. Cloggett, F.G., and Wong, J., Salmon Canning Wastewater Clarification, Part I. Fisheries Research Board of Canada, Vancouver Laboratory, British Columbia, January, 1968.
13. Mendenhall, V., Utilization and Disposal of Crab and Shrimp Wastes, University of Alaska, Marine Advisory Bulletin No. 2. NTIS, COM-71-01092, March, 1971.
14. Novak, A.F., Summary of the First Meeting of Sea Grant Food Science and Technology, May 24, 1970. Sea Grant Marine Advisory Program, Oregon State University, Corvallis.
15. Rousseau, J.E., Jr., Shrimp Waste Meal; Effect of Storage Variables on Pigment Content. Commercial Fisheries Review 22 (4).
16. Burkholder, P.R., et al, Nutritive Value of Shrimp Flour, Nature 211:860-861.
17. Schmidt, P.J., and Baker, E.G., Indirect Pigmentation of Salmon and Trout Flesh with Conthaxanthin, Journal of the Fisheries Research Board of Canada, 26: 357-360.
18. Standard Method For the Examination of Water and Wastewater, American Public Health Association, 13th Edition, 1971.

SECTION XI

APPENDICES

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APPENDIX A

BENCH SCALE TEST PROCEDURES

JAR TEST

The screening of coagulants and flocculants for possible flotation use was accomplished by the conventional jar test described as follows:

1. To obtain the approximate coagulant dosage, one liter of wastewater at pH 7.3 was slowly stirred and a 1% alum solution added until floc formation was observed (120 mg/l).
2. To obtain optimal pH, five beakers containing one liter of shrimp cannery wastewater were employed with respective adjustment of pH to 3.0, 5.0, 6.0, 7.5, and 9.5. The alum dosage obtained from step one was then introduced during a three minute rapid mix (at 100 rpm) period. This was followed by slow mixing at 20 rpm for 20 minutes to enhance flocculation. After 20 minutes of sedimentation, the supernatants were analyzed for TOC and the optimum pH obtained (5.0). 4 mg/l of Anionic polymer was added to each beaker towards the end of the rapid mix period.
3. To determine the optimal coagulant and flocculant dosages, wastewater samples were adjusted to pH 5.0. The jars were then rapid mixed with dosages of alum of 0, 30, 80, 120, and 240 mg/l. 4 mg/l Anionic 835A polymer was introduced at the end of the rapid mix period. Mixing conditions and analysis was identical to that described in step two.

Next using an alum concentration of 80 mg/l at pH 5.0, the Anionic 835A dosage was varied at 0, 1, 2, 4, and 8 mg/l and optimal dosage determined.

4. The procedure employed to evaluate other coagulants and flocculants was similar to that described above. The pH was maintained at 5.0 except for the lime study where the lime dosage itself determined the pH.

AIR FLOTATION BOMB

The effect of varying operating conditions on the dissolved air flotation process for the shrimp wastewater was evaluated by employing a flotation cell as shown in Figure 13. The laboratory procedure as suggested by Eckenfelder and Ford is outlined as follows:

1. A two liter sample of wastewater (if direct pressurization was used) was introduced into the pressure chamber. Prior to addition, the pH of the sample was adjusted to pH 5.0 and alum when necessary added.
2. Compressed air was applied to the pressure chamber to attain the desired operating pressure (30 to 60 psi).
3. The air-liquid mixture in the pressure bomb was shaken for one minute and allowed to stand for three minutes to attain saturation.
4. The wastewater was next transferred to a graduate glass cylinder where polymer was added. For the pressurized recycle investigation, a measured volume of effluent (computed from the desired recycle ratio) was pressurized and released to the appropriate volume of raw wastewater in the graduate cylinder.
5. After flotation separation in the graduate was completed (approximately 20 minutes), the clarified effluent was siphoned and analyzed for total organic carbon.

SLUDGE DRAINAGE

The effect of pilot plant chemicals on the floated sludge was evaluated by a settling test in a 1,000 ml graduated cylinder. The procedure was as follows:

1. A 1,000 ml graduated cylinder was filled with the sludge skimmings from the DAF pilot plant.
2. An interface of floating sludge and water formed. Periodic readings of total time elapsed and interface height were taken.
3. A plot was made of interface height versus time. The slope of this line at any point was the drainage rate. The plots are shown in Figures 14 through 21.

BUCHNER FUNNEL

The dewatering characteristics of the DAF process sludge by vacuum filtration was investigated by the Buchner funnel test method. The method used follows:

1. A conventional Buchner funnel, vacuum flask and vacuum pump setup was used.
2. A filter screen and filter cloth was placed in the bottom of the Buchner funnel.
3. The filter cloth was wet with distilled water and a 0.51 m (20-inch) Hg vacuum was pulled on the vacuum flask.
4. 200 ml of sludge well mixed with a polymer was placed in the Buchner funnel.
5. The volume of sludge drawn through the filter was recorded every 15 seconds until the vacuum broke.
6. The filtered volume was plotted against time and a slope computed.

APPENDIX B
LABORATORY ANALYTICAL METHODS
AND SAMPLING PROCEDURES

COMPOSITE SAMPLING

Flow proportional samples were collected periodically during the pilot plant runs and while sampling for the wastewater surveys. The samples were collected every 15 minutes during the pilot plant work because of the short run times. Samples were collected and flow meters read hourly during the wastewater survey at Plant A. All samples were plant day composites which varied from 2 hours to 12 hours. A shorter interval would have been desirable because of short plant runs, however, because of the large number of sample locations, one sampling run took approximately 45 minutes. The samples were mixed with previously collected samples for a given sample station immediately after collection. The mixed samples were refrigerated at approximately 5° C. Analyses usually began immediately after the composite was collected and was complete approximately 24 hours later.

SAMPLE PREPARATION

All samples were collected as they were leaving the plant process or discharge being sampled. No screening of settleable solids were done by the investigators. Some of the wastewaters were screened by the plant, however. This was explained in Section VI, Wastewater Surveys.

There was no sample preparation for the settleable solids test. Settleable solids were read from the raw water as collected. The wastewater used for the settleable solids test was not re-used for the remaining tests. The hourly sample quantity at each station was adjusted daily after an estimated plant run time was received so that approximately 1.5 liters were collected at each station. This was sufficient volume to perform all tests.

The composite sample remaining after the settleable solids test was blended in a food

blender at high speed for approximately 30 seconds. This was necessary because of the large amount of shrimp flesh and shell fragments in most of the samples and the extreme difficulty in pipetting small representative volumes. After blending, a separate sample for Kjeldahl nitrogen was acidified according to "Standard Methods" (18).

CHEMICAL OXYGEN DEMAND

The COD sample was withdrawn from a blended, well mixed composite sample and diluted in a volumetric flask because the COD for most of the waste streams was strong. The COD was then analyzed by the dichromate reflux method of "Standard Methods" (18) for a 10 ml sample. Because of the high chloride content of the wastewater control, tests were performed to optimize the dosage of mercuric sulfate. A dose of 0.2 grams per sample was sufficient. A reflux time of 2 hours was used for all determinations.

BIOCHEMICAL OXYGEN DEMAND

The "Standard Methods" (18) procedure was used for BOD-5 determinations. A Delta Scientific Model 85 oxygen meter with a BOD bottle fitted agitated probe was used for D.O. determinations. All samples were neutralized to pH 7.0 before dilution in the BOD bottles. The dilution water was not seeded because of the extreme biodegradability of the wastewater samples. The D.O. was measured in each bottle prior to incubation and after incubation.

pH

A Photovolt Model 85 A pH meter was used for all pH measurements. The meter was standardized daily with standard buffer.

TURBIDITY AND ORTHOPHOSPHATE

A Hach Model DR filter photometer was used for these measurements. Samples were diluted in order to make mid-range readings. For orthophosphate determinations the sample was filtered prior to dilution and reagent addition.

OIL AND GREASE

The ASTM standard test (D1340-60) for Oily Matter in Industrial Waste Water

was used with revisions for oil and grease determinations. Two extractions were made with hexane on an acidified sample. The oil-solvent layer was placed in a tared Erlenmeyer flask. The solvent was then condensed at a very low heat, the flask was dried at 103° C, cooled in a dessicator and weighed. The residual was computed in mg/l and reported as oil and grease.

ALKALINITY

The alkalinity was determined by titration with 0.02 N H₂ SO₄. The titration end point for total alkalinity was determined by constructing a titration curve for each sample location and titrating to the end point by using a pH meter.

SOLIDS

Total solids were determined by first evaporating to dryness 50 ml of sample in a tared evaporation dish at 103° C. The dish was then cooled in a dessicator and weighed with an analytical balance. The residue was reported as total solids in mg/l. The residue was then ignited in a muffle furnace at 600° C for 15 minutes, allowed to cool in a dessicator and again weighed. The remaining residual was reported as total fixed solids in mg/l. The difference in the two values was reported as total volatile solids.

Suspended solids were determined by first filtering a sample through a tared asbestos mat filter. The tared crucible containing the filter and filter residue was dried at 103° C. The dish was then cooled in a dessicator and weighed. The residue was reported as total suspended solids in mg/l. The same procedure as above was used for determining fixed suspended solids and volatile suspended solids.

Dissolved solids were determined by subtracting suspended solids values from total solids values.

SETTLABLE SOLIDS

Settleable solids were determined by filling a 1,000 ml Imhoff cone with an unblended, unscreened sample. The sample was allowed to settle for 45 minutes and then the cone was gently turned several times to loosen solids sticking to the sides of the cone. The sample was then allowed to settle for an additional 15 minutes. The settleable solids in ml/l were then read from the graduated cone.

PROTEIN

The "Standard Methods" (18) procedure was used for organic Kjeldahl nitrogen. The protein concentration was obtained by multiplying the organic Kjeldahl nitrogen concentration by 6.25.

APPENDIX C

COST STUDY DATA

GENERAL

Cost study data includes estimated costs (January, 1974) of the following:

1. Basic wastewater treatment operations,
2. Auxiliary operations to the basic operations above,
3. Plant piping and process changes,
4. Solid waste disposal operations,
5. Operation and maintenance costs.

The first four groups constitute a complete treatment and disposal system. A schematic of the system is shown in Figure 31. Estimated treatment costs of each of the four groups above are made for two basic shrimp canning plant sizes; an 8 peeler plant with a total process wastewater discharge of 600 gpm ($0.0378 \text{ m}^3/\text{sec.}$), and a 4 peeler plant with a total process wastewater discharge of 300 gpm ($0.0189 \text{ m}^3/\text{sec.}$). For plants of different peeling capacities than listed above, one can interpolate between the two costs given to obtain a reasonable estimate.

Basic wastewater treatment operations include the following:

1. Screening by tangential screens.
2. Dissolved air flotation (DAF) cell complete with flocculation tank, pressurization pump and tank, recycle piping, sludge scraper mechanism, sludge hopper and sludge removal pump.
3. Sludge dewatering by centrifugation.

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4. Wet hauling of screenings and dewatered sludge to a landfill.

Auxiliary wastewater treatment operations will greatly increase the efficiency of the DAF unit and may be required by enforcement agencies. The auxiliary operations are:

1. Chemical coagulant feed system.
2. Polymer feed system.
3. Acid feed system with automatic pH control at pH 5.0.
4. Caustic feed system to treated effluent to meet pH discharge standards.

Plant piping and process changes cost estimates are given for the following:

1. Conversion from wet fluming of shrimp to dry conveying.
2. Separation of concentrated wastewaters and relatively clean wastewaters.

Solid waste disposal operations include the following:

1. Screenings dewatering.
2. Drying of dewatered screenings and sludge.
3. Air pollution control devices for the dryer.
4. Grinding of dried solids.

Operation and maintenance costs include the following:

1. Salary of an operator.
2. Maintenance costs including power.
3. Chemical costs.

The cost estimates given are for a finished installation, therefore, the costs include equipment and installation costs. The cost estimates for each of the above groups follows:

BASIC TREATMENT SYSTEM

	<u>Item</u>	4-Peeler	8-Peeler
		<u>Plant</u> <u>Cost</u>	<u>Plant</u> <u>Cost</u>
1.	Screens	\$ 7,500	\$ 15,000
2.	Pump to Screens	1,800	2,300
3.	Dissolved Air Flotation Unit	45,000	60,000
4.	Pump to DAF Unit	1,800	2,300
5.	Dewatered Sludge Pump	4,300	7,500
6.	Dewatering Centrifuge & Pump	30,000	35,000
7.	Screenings Conveyor	3,700	3,700
8.	Dewatered Sludge - Screenings Holding Tank	8,000	12,000
9.	Tank Truck	20,000	25,000
10.	Miscellaneous	5,000	10,000
	Total	<u>\$127,100</u>	<u>\$172,800</u>

AUXILIARY OPERATIONS TO DAF UNIT

1.	Coagulant Feed System	\$ 3,800	\$ 4,200
2.	Polymer Feed System	4,500	5,000
3.	Acid Feed System with Automatic pH Control	14,000	16,000
4.	Caustic Feed System	9,000	10,000
	Total	<u>\$ 31,300</u>	<u>\$ 35,200</u>

IN PLANT CHANGES

1.	Conversion from Wet Fluming of Shrimp to Dry Conveying	\$ 12,000	\$ 20,000
2.	Separation of Waste Discharges to Clean and Polluted Wastewaters	3,000	5,600
	Total	<u>\$ 15,000</u>	<u>\$ 25,600</u>

SOLID WASTE DISPOSAL

<u>Item</u>	<u>4-Peeler Plant Cost</u>	<u>8-Peeler Plant Cost</u>
1. Screenings Dewatering with a Compactor	\$ 3,000	\$ 3,700
2. Rotary Dryer for Dewatered Screenings and Sludge	53,000	68,000
3. Dryer Afterburner	23,500	30,000
4. Grinder	1,800	2,250
5. Building	7,500	10,000
6. Miscellaneous - Contingencies & Equip. Foundations	2,000	2,400
Total	<u>\$ 90,800</u>	<u>\$116,450</u>

OPERATION & MAINTENANCE

<u>A. Basic Treatment</u>	<u>Cost/Day^a</u>	<u>Cost/Day^a</u>
1. Operator - Treatment Plant 8 hours @ \$4.00/hour	\$ 32.00	\$ 32.00
2. Driver - Solid Wastes 8 hours @ \$3.00/hour	24.00	24.00
3. Land fill fee \$5.00/Load	15.00	25.00
4. Tank Truck \$0.25/mile	15.00	15.00
5. Maintenance and Power @ 1¢/kwh	6.80	8.00
Total	<u>\$ 92.80</u>	<u>\$ 104.00</u>
 <u>B. Auxiliary Operations</u>		
1. Alum \$0.05/pound	\$ 6.00	\$ 12.00
2. Polymer \$1.75/pound	4.38	8.75
3. Acid \$40.00/ton	10.00	20.00
4. Caustic 50% @ \$.50/Gal	4.25	8.50
5. Power - 2 Hp = 1.5 kw 1¢/kwh	.10	.12
6. Maintenance	2.00	2.00
Total	<u>\$ 28.83</u>	<u>51.37</u>

a - A Day is defined as 8 hours of operation.

OPERATION & MAINTENANCE (Continued)

<u>Item</u>	<u>4-Peeler Plant Cost/Day</u>	<u>8-Peeler Plant Cost/Day</u>
C. Solid Waste Disposal		
1. Operator 8 hours @ \$3.00/hour	\$ 24.00	\$ 24.00
2. Dryer Fuel \$0.75/1,000 cf of Nat. Gas	16.50	33.00
3. Power 1¢/kwh	1.00	1.20
4. Packaging	2.50	5.00
5. Maintenance	3.00	4.00
Total	\$ 47.00	\$ 67.20

SUMMARY

Capital Costs are:

	<u>Cost</u>	<u>Cost</u>
Basic Treatment System	\$ 127,000	\$ 172,800
Basic Treatment System plus Auxiliary Chemical Operations	158,300	208,000
Basic Treatment System plus Auxiliary Chemical Operations plus solids drying system. (Holding Tank and Tank Truck eliminated)	221,100	287,450

The operation and maintenance costs/day are:

	<u>Cost/Day</u>	<u>Cost/Day</u>
Basic Treatment System	\$ 92.80	\$ 104.00
Basic Treatment System plus Auxiliary Chemical Operations	121.03	155.37
Basic Treatment System plus Auxiliary Chemical Operations plus Solids Drying system. (Tank truck, driver and land fill fee eliminated)	114.03	158.57

It must be emphasized that the above operation and maintenance cost estimates are based on 8 hours of treatment plant operation per day. If a plant processes for only 2 hours, then the operation and maintenance costs will be approximately 25% of the costs shown above.

Total costs/day include amortization of capital costs plus operation and maintenance costs. Amortization is based on 120 operating days per year, annual interest of 7% and an equipment life of 10 years. Operation and maintenance costs are based on 8 hours of processing. Taxes are not considered.

Total Costs/day are:

	4-peeler Plant <u>Cost/Day</u>	8-peeler Plant <u>Cost/Day</u>
Basic Treatment System	\$ 154.40	\$208.22
Basic Treatment System plus Auxiliary Chemical Operations	216.46	280.83
Basic Treatment System plus Auxiliary Chemical Operations plus Solids Drying System (Tank truck, driver and holding tank eliminated).	248.23	332.05

To obtain the treatment costs for a cannery of different size than the two listed, a reasonable estimate can be obtained by straight line interpolation.

APPENDIX D
MEMBER CANNERS
AMERICAN SHRIMP CANNERS ASSOCIATION

Sponsor of this Shrimp Canning Waste Treatment Study was the American Shrimp Canners Association, P. O. Box 50774, New Orleans, Louisiana, 70150. Member canners are listed below:

Biloxi Canning Co., Inc. P. O. Box 1168 Biloxi, Mississippi 39533	Mr. D. J. Venus
Authement Packing Co., Inc. P. O. Box 380 Dulac, Louisiana 70353	Mr. Huey Authement
Calvin J. Authement Packing Co., Inc. Grand Caillou Box 311 Houma, Louisiana 70360	Mr. Calvin J. Authement
Buquet Canning Co. P. O. Box 909 Houma, Louisiana 70360	Mr. A. J. Buquet
C. C. Canning Co., Inc. P. O. Box 12 Biloxi, Mississippi 39533	Mr. William Cruso, Jr.
Cutcher Canning Co., Inc. P. O. Box 8 Westwego, Louisiana 70094	Mr. A. J. Cuccia, Jr.
DeJean Packing Co. P. O. Box 509 Biloxi, Mississippi 39533	Mr. R. H. Sewell
Deepsouth Packing Co., Inc. P. O. Box 13145 New Orleans, Louisiana 70125	Mr. Ray Skrmetta
Grand Caillou Packing Co., Inc. P. O. Box 430 Houma, Louisiana 70360	Mr. Emile Lapeyre, Jr.
Gulf Coast Packing Co., Inc. Grand Caillou Route Houma, Louisiana 70360	Mr. Richard B. Samanie

Indian Ridge Canning Co., Inc.
P. O. Box 550
Houma, Louisiana 70360

Mr. Gordon Millet

Johnson Seafood Co.
P. O. Box 117
Biloxi, Mississippi 39533

Mrs. Louis Johnson

Louisiana Packing Co., Inc.
P. O. Box 129
Chauvin, Louisiana 70360

Mr. Lynn Chauvin

Mavar Shrimp & Oyster Co., Ltd.
P. O. Drawer 208
Biloxi, Mississippi 39533

Mr. Vic Mavar

Reuther's Seafood Co., Inc.
P. O. Box 50773
New Orleans, Louisiana 70150

Mr. C. G. Reuther, Jr.

Robinson Canning Co., Inc.
P. O. Box 10
Westwego, Louisiana 70094

Mr. Alan J. Robinson

Sea Coast Co., Inc.
P. O. Box 502
Biloxi, Mississippi 39533

Mr. Nick Cerinich

Southern Shell Fish Co., Inc.
P. O. Box 97
Harvey, Louisiana 70058

Mr. Victor Blereau

Southern Shell Fish Co., Inc.
P. O. Box 162
Biloxi, Mississippi 39533

Mr. Delacruz

Southland Canning & Pkg. Co., Inc.
P. O. Box 23220
New Orleans, Louisiana 70123

Mr. Paul P. Selley

Trosclair Canning Co.
P. O. Box 67
Cameron, Louisiana 70631

Mr. Roland Trosclair, Jr.

Weems Brothers Seafood Co.
1124 East Bay View
Biloxi, Mississippi 39530

Mr. Charles Weems

LeTur Foods Co., Inc.
P. O. Box 1163
Slidell, Louisiana 70458

Mr. James J. Tur

The consulting engineer for this project was Domingue, Szabo & Associates, Inc.,
P. O. Box 52115, Lafayette, Louisiana 70501.